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REPORT ON THE PYRITE AND PYRRHOTITE VEINS IN JEFFERSON AND ST. LAWRENCE COUNTIES, NEW YORK

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State Defense Council
Albany, New York.

SIR: The mineral Pyrite is of imperative importance in the manufacture of munitions and fertilizers. The present American production is unequal to our needs. For this reason this resurvey of the Pyrite deposits of New York has been undertaken at the suggestion of the War Minerals Committee, in affiliation with the Council of National Defense and under the auspices of the New York State Defense Council. This resurvey and report indicate that this State carries large natural supplies of Pyrite, and that the present production is far below possible production under favorable market conditions.

VERY RESPECTFULLY SUBMITTED

JOHN M. CLARKE
State Geologist
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National Research Council

PYRITE AND PYRRHOTITE VEINS IN JEFFERSON AND ST. LAWRENCE COUNTIES, NEW YORK

By A. F. Buddington

INTRODUCTION

This report is based on field work carried on during the month of August, 1917. Its purpose is to direct attention to many undeveloped veins in these two counties which are now available as sources for sulphur ore in commercial quantities and quality.

The pyrite veins of St. Lawrence County have been previously described from the viewpoint of their origin by Dr. C. H. Smyth, Jr., whose report has been of the greatest assistance in this investigation. Those of Jefferson County had been previously noted by D. H. Newland in connection with work on the hematite iron ores of this district. The reader is referred to the report by Smyth in the New York State Museum Bulletin 158, for further details as to the origin of the ores.

Distribution of Pyrite and Pyrrhotite Veins in St. Lawrence and Jefferson Counties

Roughly, the pyrite and pyrrhotite veins investigated lie in 7 long narrow belts, 5 of which — all the important ones — may be grouped in one belt 40 miles long and 3–4 miles wide which stretches in a NE and SW direction across 5 quadrangles; the Canton, Hermon, Gouverneur, Hammond, and Antwerp. These seven belts comprise: (1) the belt of gabbro consisting in part of two bosses of gabbro located at Pyrites and the Stella mines respectively, and connected by a very narrow neck, (2) a narrow belt of Grenville gneiss lying almost wholly in the town of DeKalb and running NE from Cole mine, in the town of Gouverneur through the village of Bigelow, referred to here as the Bigelow belt, (3) a belt of gneiss, averaging about a mile in width, where not cut out by granite, which can be traced continuously, except for a short break, for 50 miles through the towns of Pierrepont, Russell, Hermon, Fowler, Rossie, Antwerp, and Philadelphia; it is in this belt that the more important undeveloped pyrite veins lie; (4) a narrow belt, here called the Laidlaw belt, in the town of Antwerp running from Halls Corners to Oxbow — this is simply the northwest limb of an isoclinal syncline

of gneiss of which the Keene-Antwerp belt is the southeastern limb, the two limbs connecting each with other along the strike at Hall's Corners; (5) a bed of rusty gneiss intercalated in the limestones, about a mile long, and located about 2–3 miles SW of Oxbow; (6) a long narrow belt of gneiss lying about ½ mile west of Sylvia Lake running north, then northeast, and then east to the village of Fowler, and here referred to as the Kilburn belt; (7) the border of an anticlinal area of gneiss in the town of Edwards northeast of Pleasant Valley School.

All the veins of importance occur in gneiss of similar character, viz., in what is known to Adirondack geologists as one phase of the Grenville gneiss.

Structure of Veins

The Grenville gneisses and limestones associated with the pyrite veins have suffered severe compression and have been folded tightly together and overturned so as to now dip in general quite uniformly to the northwest, as is well illustrated by the isoclinal syncline NW of Antwerp. They have also been intruded by masses of granite. But Smyth has concluded that the pyrite veins were formed subsequent to this intense period of metamorphism and intrusion, although they maintain a persistent parallelism to the foliation with a general NW dip.

The zones of rusty gneiss which usually carry the ore veins are narrow bands with a lineal extent measurable in miles. The veins themselves are thin tabular bodies or sheets lying parallel to the foliation of the gneiss (Fig. 1). All the data at hand indicate that the veins are in general quite uniform in thickness and are persistent for very considerable distances along the strike and down the dip. At all the outcrops examined the veins can be traced along the strike for at least several hundred feet by natural exposures and their inferred lengths are usually several times longer. At the Stella mines the Stella vein was developed for a length of 1200 feet and the Anna veins are being mined for a length of 1800 feet and are known to have a total length of about half a mile. The vein at Pyrites can likewise be traced for about 3/5 of a mile along the strike. The veins at the Anna shaft have been opened up to a depth of about 600 feet down the dip, and the Stella vein was mined 900 feet down the dip without showing any change in character.

Grenville Gneiss

The gneiss which carries the pyritic zones, although outcropping in belts many miles apart, yet shows for the most part only

minor variations in character. This is due to the fact that it is not of simple origin but is a composite or mixed rock formed partly of material of sedimentary origin, such as shales or sandstone constituting a portion of the Grenville series but predominantly of granitic material introduced during the intrusion of the numerous bodies and sheets of granite so common throughout this district.

The more volatile gases and solutions given off by the granitic magmas in the process of consolidation under the high pressures and heavy load of overlying rock which then existed, simply soaked through and through and saturated that portion of the Grenville series from which most of these gneisses were derived. In the form of pegmatite veins they penetrated the Grenville rock so intimately along its bedding planes as to form the dominant portion of the resultant rock. Not only did this injection take place but the sedimentary material itself was disintegrated, partially assimilated, and completely recrystallized by the current of granite juices or solutions forced through them. Furthermore, in the vicinity of the Anna and Stella mines at Hermon, bands of gabbro have undergone similar granitization, so as to be almost if not wholly indistinguishable from the granitized Grenville rocks. It is thus evident that these gneisses, although now quite uniformly of granitic composition, may originally have had quite widely diverse characters which have been masked or more or less completely wiped out by subsequent modifications.

Associated with the gneisses however there are occasional quartzitic beds ,usually micaceous and bluish gray in color, and more rarely sillimanitic and richly garnetiferous beds. Bands of amphibolite are also frequently common in the gneisses and are believed to have resulted from the alteration and metamorphism of limestone bands. Lenses of coarse-grained pyroxene rock are found in the Kilburn and West Oxbow belts. These are also the result of contact metamorphism of limestones.

That most of these gneisses under consideration here are really modifications of sedimentary beds of the Grenville series is indicated: by their frequent interbedding with limestones; by the occasional presence of truly quartzite beds; by their form of outcrop in long narrow belts; and by the usual abundance of garnets, common sericitic bands, and occasional presence of sillimanite, so characteristic of metamorphosed sedimentary material.

The usual character of the fresh gneiss is that of a light bluish gray rock composed essentially of quartz, feldspar, and biotite with accessory minerals. Of the latter, garnet is the most common and

abundant. It occurs disseminated through the rock in small red crystals up to 1/4 inch in diameter being especially prominent in the pegmatite veins. Bands of muscovite or white mica gneiss are prominent in the Bigelow and Kilburn belts. Grains of pyrite are, at least, sparsely distributed throughout all the gneiss.

The rock is a typical injection gneiss, the pegmatite veins parallel to the foliation being so abundant and their contacts often being so blended with the wall rock as to render their discrimination as such veins difficult. Many of these veins, particularly those which are best defined, carry black tourmaline and nearly all carry garnets, probably the result of assimilation and recrystallization of the country rock. Pegmatite veins, usually much wider than those parallel to the foliation, are also found breaking across the foliation of the rock.

Rusty gneiss. The pyritic zones or what are usually very appropriately called the "rusty gneisses," are not unique features of the gneiss belts but simply represent bands, lenses, or portions of the gneiss itself which have been more or less altered and replaced by pyrite bearing solutions. Pyrite in sparsely disseminated grains is almost universally present throughout all the gneisses, and the rusty beds represent merely those portions in which the pyrite is in sufficient quantity to produce on weathering the iron-rust color of the surface outcrop. The rusty gneiss usually carries five per cent or more of pyrite but it is only where the thin sheets of the rusty gneiss are locally replaced by pyrite to the extent of 15–40 per cent with a general average of 20 per cent or so that they assume commercial importance.

The veins may occasionally pinch to a fraction of their normal width or swell to several times their usual thickness, but in general they are quite uniform over very considerable areas. When considered on a large scale these veins are perhaps to be regarded as very much flattened lenses with at least one very long diameter in the line of strike. Although formed by partial replacement of sheets of the gneiss yet in their parallelism to the foliation of the gneiss, in their uniformity of character, and in their great length and persistence they have the appearance and gross structural relations of "bedded veins."

General Character of Ore

The Pyrite veins show two rather different types of ore: one, by far the most usual type, that in which the pyrite is distributed

Fig. 1. Outcrop of Pyrite vein on right bank of Grasse river, ½-mile north of Pyrites

more or less uniformly through the gangue and the other, a sheeted zone in which layers of rich pyrite ore alternate with leaner bands. The latter type is found at the Kilburn property, above the main ore vein at the Hendricks shaft, and at the Bent Farm, S. W. of Oxbow.

The ore at the Stella mines may be taken as representative of the average type and character of the ore. The ore of the veins at Pyrites, Ore Bed School, Keen, Morgan, Laidlaw, and the veins three quarters of a mile northeast of the Bent pit is all very similar in quantity and character to that of the Stella mines. The ore here consists of fine granular pyrite disseminated quite uniformly through the gangue, and of medium pyrite, disseminated through the gangue, bunched together in small irregular clot shaped pockets, or joined together by a close woven network of veinlets. The gangue is an aggregate of very fine chloritic material — the result of the alteration and replacement of the gneiss — associated with varying amounts of quartz, feldspar, mica, and finely disseminated graphite. The chlorite substance is deep green where exposed at the surface but in the workings of the Stella mines and at the Cole mine, it is light gray or white. This is the average ore, and as it comes from the mine it runs 20 per cent in sulphur. As a rule, richer ore is associated with an increase in the graphite content and with a greater chloritization.

The pyrite in the ore at the Farr shaft is more markedly coarsely granular, disseminated in character, and somewhat richer than the average run of the Stella mines. This coarser disseminated character of the pyrite frequently appears in the richer bands of the Styles shaft, Hendricks shaft and elsewhere. The ore from the prospect pits near the Cole mine is different from that of any of the other veins. It is more markedly loosely granular throughout and is banded in alternating coarser and finer layers, affording very handsome specimens. The ore in the veins of the southwestern half of the Keene-Antwerp belt also has its own peculiar character. Here the pyrite occurs in a veinlet system of much coarser character, vein and gangue being more sharply differentiated, and is to a large extent of much coarser grain than the ore of the Stella mines. Crystals up to an inch or more are common. Many of the veins stand out sharply from the gangue, although the latter as usual carries considerable pyrite of finer grain. The pyrite-pyrrhotite ore in the prospect pit a mile S. W. of Pyrites is of this general character. The pyrrhotite in the veins at the Laidlaw and Mitchell shafts occurs in a manner similar to the pyrite at the Stella mines, whereas the pyrrhotite near Pleasant Valley school is very coarsely granular with very little gangue.

The gangue of all the veins shows only minor variations from that at the Stella mines. It is simply a chloritized altered portion of the pegmatitized Grenville gneiss consisting of quartz, feldspar, chlorite, mica, and graphite, the latter mineral finely disseminated in small amounts.

Pyrrhotite occurs both as well defined separate veins associated with the pyrite veins and also as small irregular sporadic masses within the pyrite veins themselves. At the Mitchell shaft a well defined 3-foot vein of pyrrhotite runs through the center of the pyrite vein; at the Laidlaw vein a 7-foot vein of pyrrhotite occurs in the footwall of the pyrite; at prospect pit "B" near Pyrites it occurs as veinlets of pyrrhotite apparently of contemporaneous origin with similar veinlets of pyrite; whereas at the Stella, and Anna veins and at Pyrites it is found in occasional local bodies in the pyrite veins themselves.

All the veins, in general, seem to run persistently about 20–30 per cent sulphur, the pyrrhotite portions as well as the pyrite falling within these limits.

In thickness, the vein at Pyrites and the Stella vein average 10 to 12 feet; the two main veins at the Anna shaft each average 18 feet; the veins along the Bigelow belt, the Cole mine excepted, average 6 to feet; those along the Keene-Antwerp belt 10 to 20 feet; and the Laidlaw and Bent veins each show 25 feet where exposed. A maximum width of 40 feet is found in portions of the Anna veins, and 80 feet is reported to have been found on the vein at Pyrites.

The pyrite veins locally show sharp flexures, pinches, and crenulations, but these are believed to be the result of minor disturbances subsequent to the more intense period of metamorphism of the country rock. There seems to be some local pyrite enrichment in these zones of disturbance at the Farr, Cole, and Bent veins.

Surface Appearance of Veins

Pyrite ultimately breaks down quite rapidly on exposure to the air into iron hydrates or limonite which gives the yellow and reddish brown colors of iron rust to the outcrop and into sulphuric acid solutions which pass away in the ground water. In the process of formation however the latter reacts on the other minerals of the rock and together with the weakening effect of the decomposition of the pyrite and the solution of some of the rock tends to destroy the cohesion of the gneiss and cause its disintegration *in situ*. As a

result, much of the rusty gneiss near the surface crumples to a granular aggregate.

The ore zones are usually deeply weathered to a depth of several feet and only on a shoulder where erosion has proceeded faster than decomposition, or beneath a surface which has been protected by a glacial polish, can fresh specimens be obtained. The gossan of the ore is a cellular, porous, sponge-like mass of siliceous material with little if any pyrite remaining, and usually colored a reddish or brown or buff by the finely disseminated iron hydrates.

The ore veins — the sheeted zones excepted — usually present a more massive homogeneous appearance than do their wall rocks, showing coarse spheroidal weathering and rounded knobs. This more massive character is due to the greater homogenity of the veins which has arisen through the more or less uniform alteration and replacement of the gneiss with a partial obliteration of its foliated character. Locally, the glacial drift overlying the ore veins has been cemented by the iron solutions arising from the decomposition of the pyrite and forms a ferruginous conglomerate or sandstone overlying the vein.

Rocks Associated with Gneiss

The other rocks associated with the gneiss and hence with the pyrite veins may be roughly classed in six groups, limestone, a coarse red porphyritic granite, a fine grained red granite gneiss, pegmatite veins, gabbro, and Potsdam sandstone.

The gneiss carrying the pyrite veins has already been described.

The limestone, here, is the coarse crystalline marble characteristic of the Grenville formations of this district. It often includes phases and beds which are very impure, such as ophicalcite or serpentinous marbles, beds full of silicates such as diopside or other pyroxene, mica, feldspar, etc., as well as white quartzite beds and thin quartzite bands and lenses. Locally, narrow layers of granitic material are also found intruded in the limestone. These are often pyritous and rusty. Where the granite is intruded in abundant thin sheets the intervening limestone beds are often altered to green pyroxenitic or amphibolitic bands, as is the case northeast of the Bigelow band of gneiss and northeast of Ore Bed School.

The coarse porphyritic granite may pass over into a rock of syenitic character through the diminution of the quartz. The typical rock is gneissoid with abundant large lenticular crystals of feldspar in a ground mass of quartz, feldspar, and biotite or hornblende. As

representative masses we may name the body of granite forming Reservoir Hill east of Gouverneur, Moss Ridge, the sheet of granite bordering the Keene gneiss belt on the southeast, and the mass of granite south of Oxbow.

The fine grained granite gneiss is of fine to medium grain with a gneissic structure which varies considerably in its degree of development. The rock is characterized by a high quartz content and the sparse amount of ferro-magnesian minerals. It is composed of quartz; the feldspars, orthoclase, oligoclase-andesine, microcline, and microperthite; and magnetite, apatite, and zircon in trifling amounts. These bodies of granite, where in contact with limestone, are frequently bordered by a narrow band of coarse garnet rock associated with amphibolite the result of contact metamorphism.

As representative masses of this rock may be named the body near DeKalb Junction, that in the limestone belt northeast of Gouverneur, the mass on the road running north from Hermon to Pyrites, the body east of Pyrites between there and Little River and the mass west of Payne Lake on the Hammond quadrangle.

Pegmatite which represents the later and more mobile and fluid products of consolidation or crystallization of the grantic magmas, is omnipresent and often constitutes the bulk of the gneisses They are also present in the gabbro and granites and more rarely in the limestones. They consist in the main of quartz and feldspar, usually carrying in addition abundant garnets when present in the gneisses. One group of the pegmatite veins are conspicuous for their content of black tourmaline which is often intergrown with quartz in a graphic manner.

The pegmatite veins occur for the most part parallel to the foliation of the rock they are intruding, but to a minor extent and usually in wider dikes may break across the rock at any angle.

Some of the pegmatite veins carry a little pyrite which is probably primary while others are, together with the gneiss they are intruding, chloritized and pyritized.

The only gabbro mass associated with the pyrite veins is that at Pyrites and Hermon. This rock is so very similar to amphibolite bands in the gneisses which are usually considered to represent metamorphosed limestone beds that the question might be raised as to its being an igneous rock. The mass at the Stella and Anna mines however is connected by a narrow tongue with the bodies at Pyrites. The latter is considered by Martin to be more or less altered gabbro and the view that both masses are of igneous origin and were intruded in regular form as a basic magma into the

Grenville formation is adopted here. The conclusion that it is gabbro is based on its igneous texture, the presence of hypersthene and augite in fresh unaltered sections, and the presence within it of bands of gneiss and limestone which it tore from the enclosing rocks and included in itself.

The gabbro is a medium to coarse-grained dark gray to black rock with a very wide range in its degree of foliation but usually far more massive and with a much less conspicuous gneissic structure than the more acid gneisses. It consists of augite and hornblende, plagioclase feldspar, and minor amounts of biotite, magnetite, pyrite, and apatite. The biotite, even when present in small amount, is very conspicuous on the foliation planes. The hornblende is certainly partly and probably largely the product of alteration of augite, a mineral normal to a gabbro. This alteration of the augite to the hornblende is largely responsible for reducing the rock to a character so similar to the amphibolites which are believed to result from the contact metamorphism of limestone beds. Good solid specimens of the gabbro may be obtained in the railroad cuts at the Stella mines.

Local bands of the gabbro at the Stella mines have been so altered by the effect of granitic and pegmatitic intrusions that their original character can only be inferred from their field relations. This is especially the case with the narrow band which connects the Pyrites body and that at the Stella mines. Were one not able to trace this band continuously into the Pyrites mass of solid gabbro, there might be grave question as to its origin since it is so highly granitized as to mask completely its gabbroic character and would pass for a quartz hornblende biotite gneiss.

Rarely, narrow lenses of the gabbro and small patches up to several feet in diameter are slightly pyritic and weather rusty, but in general the gabbro is quite free from rusty phases and carries no ore.

Throughout this district, particularly in the valleys eroded in the limestones, there are found remnants of Potsdam sandstone resting unconformably upon the underlying Precambrian rocks. These sandstone patches, even though they be present in thicknesses of a hundred feet or more, form nevertheless only a thin veneer or cap above the Precambrian rocks. They formerly constituted a continuous sheet or blanket over the whole country, but by far the larger portion has been eroded, exposing the rocks now outcropping

at the surface, although many irregular patches still remain as disconnected remnants concealing the Precambrian rocks — usually Grenville — which everywhere underlie them at shallow depths.

Most of the sandstone is usually a light colored white or buff medium-grained granular rock. The basal beds are often conglomeratic and of a deep reddish color, but these may be missing. The beds have a flat dip, never more than thirty degrees, and are quite irregular in their direction of dip although their strike usually parallels that of the underlying rocks.

Origin of Veins

A thorough discussion by Dr. C. H. Smyth, Jr., of the origin of the pyrite veins of St. Lawrence county will be found in the Report of the Director, New York State Museum for 1912. The veins of Jefferson County are of similar character and origin. Smyth's conclusions stated baldly are that the workable pyrite veins are for the most part the result of replacement of sheared or fractured zones in the Grenville gneiss by magmatic solutions rich in hydrogen sulphide and iron. The sulphide ores were formed at a late period in the history of igneous activity, after the pegmatitic injection, and the source is ascribed to the emanations given off by the consolidating or cooling igneous granitic masses. The formation of the chloritic alteration product, uniformly associated with the gangue of the veins, is also ascribed to these solutions. The graphite of the veins represents in part a concentration of organic material originally present in the sediments from which the Grenville gneiss was derived and in part new material contributed directly by the magmatic solutions. The deposition of the sulphide minerals took place when the necessary lower temperatures and pressures were reached, nearer but still at considerable depth beneath the surface. The deposition was probably genetically connected with complex chemical reactions involving the precipitation, in part, simultaneously, of both graphite and pyrite.

The major reason for the restriction of the sulphide veins to the Grenville gneisses, and their comparative absence in the limestones and gabbro, is found in the difference in the physical character of the gneiss which permits its easy penetration. This is indicated in the field by the fact that the limestones are not at all, and the gabbros are only very locally, injected by pegmatite veins whereas the original sedimentary portion of the gneiss has in many cases almost disappeared in the multitude of injected pegmatite veins.

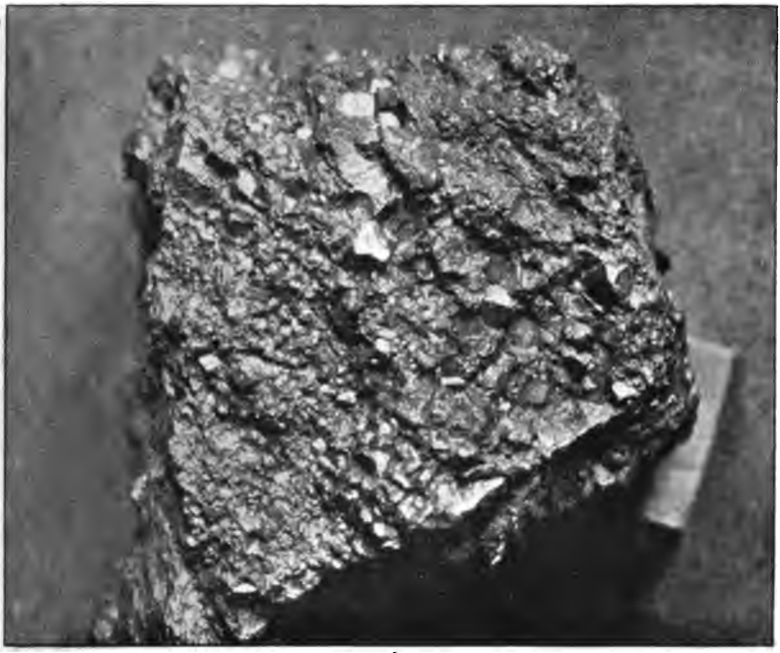

Fig. 2. Ore at the Hendricks mine with crystals of Pyrite in a chloritic aggregate

Fig. 6. The Laidlaw vein occurs along the slope of this hill

The present field work has demonstrated that the majority of the pyrite veins lie along the contact zones between the limestone and gneiss belts, or within thin beds of gneiss intercalated in the limestones. This is interpreted as meaning that during the waning stages of the period of igneous intrusion and of the consolidation of the granite magma, the greatest movements took place in the vicinity of the heavy massive limestones and the weak foliated gneiss. This formed shear zones which the succeeding sulphide bearing solutions utilized as trunk channels, altering the rock and partially replacing its constituent minerals by pyrite or pyrrhotite.

Similarly, the narrow foliated bands of Grenville gneiss enclosed in the more massive gabbro masses at the Stella mines and at Pyrites formed the more easy permeable member and therefore the channelway for the granitic emanations and the sulphide bearing solutions.

At Ore Bed school, along the east end of the Kilburn belt, along the Keene-Antwerp belt, and along the Oxbow belt, the pyrite veins are associated with hematite beds and veins in such a way that some genetic connection must exist between them. The Potsdam sandstone is also associated with the iron ore beds in such a way as to indicate that it too may have played an essential part in the conditions necessary for the formation of the ore beds. The hematite veins are usually associated with a chloritized phase of the Grenville gneiss. This alteration seems to have been the first step in the formation of the iron ore veins. These chloritic schists and gneisses were subsequently, perhaps in part contemporaneously, altered to and replaced by hematite. Because of the constant association of these ore beds with the sulphide veins it is thought that the iron in the solutions accomplishing these transformations was in most cases gained from the decomposition of a portion of the pyrite veins now eroded. If such is the case then the presence of hematite beds would suggest the possible presence of a concentration of pyrite in some nearby zone although the latter need not necessarily be sufficiently localized to constitute workable pyrite ore.

It was, however, the mere name, Ore Bed school appearing on the Gouverneur sheet which led the writer to find the pyrite veins at that locality.

The Grenville gneisses and limestones have been compressed into close isoclinal folds with a prevailing dip to the NW. The great period of metamorphism and folding of these rocks took place before the formation of the sulphide veins. Some slight folding

and flexuring however has taken place since the formation of the veins or contemporaneous with their formation as witnessed by the occasional flexuring of the veins and their local crumpling.

Summary of Pyrite Veins Occurring in Gneiss Enclosed in Gabbro

There are two bosses of gabbro, connected by a narrow neck, one at Pyrites, the other at Stellaville within which pyrite veins occur. These masses of gabbro contain included narrow sheets of Grenville sedimentary gneiss more or less injected by pegmatite and affected by granitic solutions. Three of these strips of gneiss in the Pyrites boss are known to carry pyrite veins, and two included bands of gneiss in the Stellaville lens of gabbro hold pyrite veins. The veins are always parallel to the foliation of the enclosing gneiss and gabbro.

The big vein at Pyrites runs parallel to the Grasse River for three-fifths of a mile and averages about 10–12 feet in thickness. It has been prospected at four localities and considerable ore taken out at one. A branch railroad connects Pyrites with the main line, three miles away. The vein is workable for its entire length, the ore being of average quality and coarseness, requiring milling. At the mine at Pyrites, now abandoned, the vein is reported to have averaged 16 feet thick, 22 per cent S; to have varied from 2–80 feet wide, and to have been mined to depth of 250 feet.

A bore hole at "A" prospect pit has proved ore eleven feet thick of average quality to be present.

At "B" prospect pit the ore is a mixture of pyrrhotite and pyrite. The ore is poorly exposed, is coarser in grain, but poorer quality than the average.

One vein series at the Stella mine is being worked. This consists of four parallel veins averaging 75–100 feet apart with an average aggregate thickness of 54–58 feet, a developed length of 1800 feet on the strike and depth of 600 feet on the dip. Another vein averaging 10–12 feet thick, not worked now, lies about 750 feet stratigraphically above the top of the lower ore zone. This vein was worked down the dip to a depth of 900 feet and along the strike for 1100 feet.

The ore runs 20 per cent in sulphur and is concentrated to 40 per cent at the Stella mines.

Summary of Bigelow Belt of Gneiss

Pyrite veins are exposed at seven localities along this belt of gneiss; at five shafts; in prospect pits several hundred feet S. S. E. of the Cole shaft; and as outcrops of gossan several hundred feet N. W. of the Mitchell shaft. Except at the two ends — the Cole and Farr shafts — the main pyrite veins do not run on the average over six or seven feet thick. Furthermore, the veins at the extreme northeastern end are partly pyrrhotite although the latter averages over 20% sulphur. For these reasons the belt as now exposed — the Cole mine excepted — is not as attractive a proposition for development as the Keene-Antwerp belt, although situated very favorably with respect to railroad facilities. The Cole mine, however, is now in process of redevelopment by the St. Lawrence Pyrites Co. and has shown very favorable results. The ore here averages more than 25% sulphur and is quite granular. The ore of the pyrite veins in general is similar to that of the Stella mines and would require milling.

The Bigelow belt of gneiss is a long narrow band from 500 to 1000 feet wide and 6½ miles long, tapering sharply at each end. The southern end, about four miles in length strikes on the average about north 30 degrees east (north 40 degrees east, magnetic) while the northern end — about 2½ miles long — strikes north 60 degrees east (north 70 degrees east, magnetic). The point of inflection or sharpest curvature is from one half to three fourths of a mile northeast of Bigelow.

The dip of the gneiss at the south end is 65 degrees west to vertical, and between Cole and Bigelow averages about 70 degrees west. One mile N. E. of Bigelow, where the band turns east and crosses the road, the dip suddenly flattens to 30–40 degrees N. W. and remains so for about a mile, increasing to 50 degrees or 55 degrees to the north.

The gneiss itself is, predominantly, the usual garnet biotite gneiss of granitic composition, the result of pegmatitic injection and granitization of Grenville sediments. Bands of muscovite gneiss are common, and occasional layers of amphibolite are found. Narrow bands which weather rusty owing to their disseminated pyrite content occur here and there throughout the whole belt of gneiss.

So far as development work has gone, however, the pyrite veins of economic importance are all confined to two very closely defined and localized horizons, viz., the zones located along each border of the gneiss; that is, near the contact of the limestone and the

gneiss but always within the latter. If we consider the limestone on the south as the foot wall of the gneiss belt and the limestone on the north side as the hanging wall we find that of the five shafts on the pyrite veins, two (Farr and Styles) are located in a zone of gneiss not more than thirty feet thick immediately beneath the limestone hanging wall, two (Mitchell and Hendricks) are located in a zone of gneiss not more than thirty feet thick immediately above the foot wall limestone; and one is doubtful — the Cole mine. The nearest exposure of limestone to the gneiss at the Cole mine is fifty yards southwest of the shaft. But limestone is reported to have been struck in drifts from the shaft and if so the Cole mine may lie next to the hanging wall limestone which here — owing to disturbances and change of dip — has become the foot wall, and dips northeast beneath the gneiss.

This localization of the pyrite veins so far developed to two zones raises the question as to the continuity of the veins of each zone along the line of strike. Unfortunately the zones along which the pyrite ore should occur if present is continuously covered by soil, so far as investigated by the writer, from the Cole to Farr shafts, except at one locality on the hanging wall side opposite the Mitchell shaft where outcrops of gossan are present. A small brook on each side of the belt of gneisses marks the approximate contact line of gneiss and limestone from Cole to the Hendricks shaft. Inasmuch as these veins originated through replacement of localized bands of gneisses it is surmised that they must all be lenticular in shape when considered over long distances. Hence it is probable that the shafts are not sunk on two continuous veins one on each side of the belt of gneiss. On the other hand there is every reason to believe that other lenses of pyrite with lengths equal to those now exposed do lie beneath the covering of alluvium and drift along the two zones mentioned.

This is confirmed in the northeastern half of the belt by the presence of outcrops of gossan just beneath the hanging wall limestone opposite the Mitchell shaft. The veins may be a mile in length but probably die out for a distance and then start up again at approxmiately but not absolutely the same horizon farther along their general line of strike.

At the Farr shaft the beds of limestone, gneiss, and the ore veins are all very much disturbed and closely folded. At the Cole mine similar conditions are prevalent. Both these disturbed zones are at the end of the gneiss belt, and this complex structure is probably

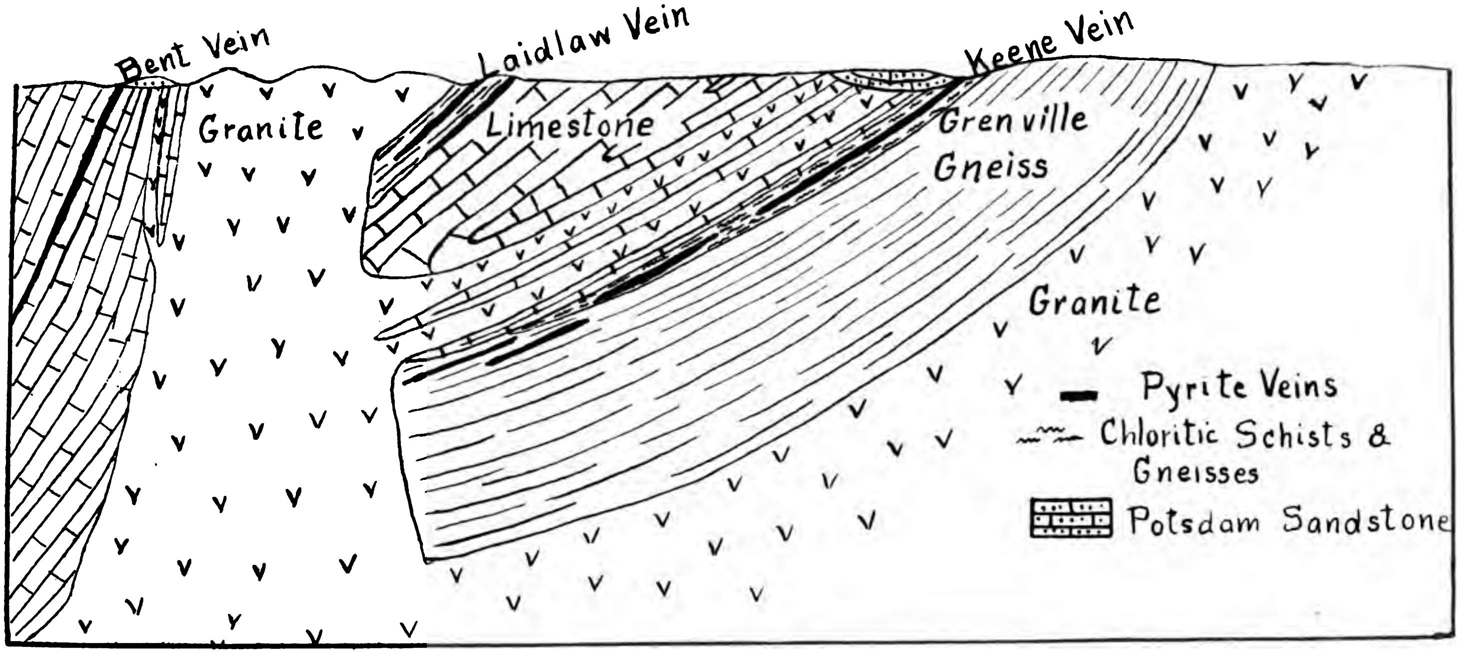

FIG. 3. Diagrammatic Structure Section to show Interrelations of Rocks and Pyrite Veins.

connected with stresses which resulted in the pinching out of the gneiss at these localities.

The pyrite vein at the Cole property is much thicker and of better quality than the other veins. At the Farr mine there is likewise greater development of sulphur bearing ore than at any of the other veins except the Cole. The suggestion arises that this greater development of ore is to some extent a result of the greater disturbances to which their wall rocks have been subjected. There is too little information bearing on this hypothesis to allow it much weight. But if there is anything in the disturbed zone theory the locality about a mile N. E. of Bigelow would bear investigating.

It has been assumed in the foregoing summary that the belt of gneiss ended a short distance S. E. of Cole. There is a small prospect for pyrite about a half mile N. E. of Dodds school. The rock here is granite gneiss — a dike in limestone — and the pit is excavated on a rusty weathering slightly pyritic phase of this granite. There is no ore but merely a little disseminated pyrite. Rock of this type does not form a part of the gneiss belt. The strike of the limestone however swings around in its direction. While it is believed that the gneiss does not continue far beyond Cole mine, a covered zone prevents any determination as to whether it does or does not.

Keene-Antwerp Belt

The series of pyrite veins lying along this belt are very favorably situated with respect to transportation facilities and at the same time show the greatest development of pyrite ore of good quality of any of the undeveloped belts. There are five localities where the pyrite veins are exposed along the belt which is 5½ miles in length. These exposures are all situated on outcropping knobs of rock above the valley levels. The trend of the veins for the greater part of the way carries them beneath lowlands filled with alluvium or drift, or beneath remnants of Potsdam sandstone. Pyrite quickly decomposes at the surface and this results in the rapid disintegration of the enclosing rock. It is therefore to be expected that a considerable portion of the pyritic zones of this belt will occur, not in the hills, but also along the valleys.

The considerable continuity in the length of the veins of this character as demonstrated at the Stella mines and at Pyrites points to a similar conclusion. It is therefore confidently believed that systematic exploration by drilling along the now covered portions of this belt would reveal a greater development of pyrite than is now

exposed. The zone which might thus be prospected is the narrow belt of greenish schists lying between the bluish gray gneiss below and the limestones above. There is a covered zone lying between the pyrite veins and the limestones to the west everywhere throughout the belt so that it is impossible to give the depth beneath the limestone at which the ore horizon lies. Indeed, it is improbable that all the exposed veins are part of one continuous vein, but rather that there are several long lenticular lenses distributed along the narrow zone of the schists, not necessarily at the same horizon. At the Morgan prospect the limestone outcrops about 350 feet above the pyrite vein. One might from this hazard a guess that the ore horizons in general lie within 500 feet or so of the base of the limestone. In disturbed zones like that at the Caledonia mine this thickness might need to be increased. The schists which hold the pyrite are for the most part of a green chloritic character with quartz often conspicuous. Portions of these schists have been altered to and replaced by beds of hematite and quartz-hematite, particularly beneath the remnants of Potsdam sandstone. These schists are but an altered phase of the underlying gneiss. The hematite veins are locally known as ore beds.

The junction of the schists and gneisses is usually well marked off by a line of hills formed by the gneiss. The latter is of granitic composition formed by the thorough injection and modification of Grenville sediments by pegmatitic and granitic solutions. It is a garnet-biotite gneiss. The limestone overlying the schists is intruded by sheets of coarse equigranular to porphyritic granitic gneiss which must not be confused with the Grenville gneiss of mixed origin lying below the schists.

Between the Keene and Caledonia prospects the pyrite ore zone probably lies beneath Potsdam sandstone most of the way. Between the Keene and Wight prospects it lies partly under sandstone and partly under a cover of alluvium. A flat meadow overlies the zone between the Wight and Old Sterling mines and between the Wight and Dickson prospects. North of the Caledonia mines the zone turns eastward and passes beneath the alluvium of Shingle Creek. Southward it is lost beneath a sand plain. Some evidences of pyrite are found along the state road about 2½ miles west of Antwerp but no definite ore veins.

The zone where the contact line between the gneiss and limestone should come was followed N. E. as far as Barnum school, but it is everywhere covered. The veins at Ore Bed school probably belong

to this belt. Some prospecting has been done in the vicinity of Hermon along the continuation of this same belt but so far only rusty gneisses have been found. The strike is in general N. E. and the dip from 25°–50° N. W. averaging about 45° N. W.

At only one locality are both the footwall and hanging wall of the veins exposed. This is at the Wight vein where the thickness is from 18–20 feet. At Ore Bed school 6 feet is exposed, at the Keene vein 9-10 feet, at the Morgan vein 8 feet, and at the Dickson vein 15 feet. All of these veins are thicker than these figures and may reach 15–20 or even more feet in width.

The percentage of sulphur in grab samples taken at the Morgan and Wight veins ran 23.24 and 28.3 respectively. The ore probably averages 20–25 per cent sulphur.

Summary of Laidlaw Belt

There are only two veins now exposed on this belt but it is very probable that other veins occur near the junction of the limestone and the gneiss beneath the covered zone to the south. This is judged to be the case from the fact that bowlders of pyrite ore are found in the glacial drift 1½ miles to the south which undoubtedly came from a source nearer at hand than the now exposed veins at the north.

The Laidlaw vein exposes at its maximum width 20 feet of pyrite ore overlying 7–10 feet of pyrrhotite ore. A sample of a specimen of the former ran 29.06 per cent sulphur and 0.22% arsenic. An average sample of the pyrrhotite ran 27.78 per cent sulphur. The whole average 20–25 per cent sulphur. The vein can be traced for 200 yards and extends for perhaps twice this distance.

Another vein, ½ mile SE, like so many of the pyrite veins, is located near the junction of the gneiss and the limestone. The vein here is in rusty gneiss and is about 7 feet thick of average quality and character pyrite ore.

These veins are 5½ miles from the railroad at Keene and 6 miles from Antwerp, and are located on a county road.

Summary of Oxbow Southwest Belt

There are two veins exposed along this belt. The northern vein is 6 feet thick as exposed, but reaches possibly a maximum of ten feet. The ore is pyrite of average quality and character. The vein can be traced for 500 yards along the strike and is enclosed in a 50–foot band of rusty gneiss intercalated in limestone.

The other vein (Bent vein) is located 7/10 of a mile SW and is in the same or a similar bed of rusty gneiss, intercalated in limestones. The vein here is 25 feet thick and a grab sample taken from different portions of the vein ran 22.15 per cent sulphur. The ore is medium granular pyrite in alternating leaner and richer bands and beds. The vein can be traced for 400 feet and probably extends much farther.

Some prospecting for hematite has been carried on in the vicinity of both these veins.

As in the case of the Laidlaw belt, there are no present facilities for transportation from these veins. The nearest railroad is at Antwerp 5 miles away, and it is 8 miles to a railroad by way of Otter Creek.

Kilburn Belt

The Kilburn prospect is the most prominent one in this belt. It is located in the town of Fowler about one and one half miles west of the village of Fowler and two fifths of a mile south of the road from the village of Fowler to West Fowler.

The prospect pit is located on a belt of gneiss in which considerable surface prospecting by small pits has been carried on throughout its length. This belt of gneiss forms the outer portion of the hills bordering the conspicuous valley running west, then southwest, and then south from the village of Fowler.

The gneiss consists for the most part of a muscovite or sericite gneiss or schist, the upper half of which weathers more or less rusty from the disseminated pyrite it contains. The gneiss is overlain and underlain by limestone.

At the top of the gneiss there is a bed of heavy granular basic rock which has the appearance of a gabbro. This rock is much more massive than the schist and disintegrates into a granular debris. This rock is probably the result of contact metamorphism of limestone beds and as is often the case with such rocks in this region the minerals are intergrown with pyrrhotite. There are two prospect pits in addition to the Kilburn pit located in this bed. They show no well defined veins and the quantity of disseminated or intergrown pyrrhotite is only comparable to the amount of pyrite found in the more rusty phases of the rusty gneisses and cannot be considered an ore.

The schist in which the Kilburn pit is located is similar to the muscovite gneiss or schist bands of the Cole belt. It is locally thoroughly injected by pegmatite veins. Its thickness is about 150

feet and the dip is 25-40 degrees northwest. At the pit itself the schist is full of some long blade like crystals with diverse or radiate orientation but which are so altered as to prevent a sight determination. Fine grained pyrite is disseminated throughout the rock in an amount common to the average rusty gneiss. In addition, thin veins up to one half inch in thickness of course granular pyrite are present parallel to the foliation, but the rock is too lean and the veins too sparse to permit the whole to pass for ore. Eight hundred tons of material are reported to have been quarried and shipped from this prospect. A trace of zinc is also reported to be present in ore from this pit.

At the northeast end of this belt of gneiss, about one-third of a mile N. W. of Fowler, there is a considerable development of hematite resting on top of the pyritous gneiss.

The conditions in the Kilburn belt offer little or no encouragement for exploitation in comparison with the other opportunities afforded by this region.

Stella Mines

These mines are located at Stellaville about one mile north of Hermon on a branch railroad running between Hermon and Dekalb Junction. They are operated by the St. Lawrence Pyrites Co. but are better known locally as the Stella Mines.

The writer is indebted for many courtesies and facilities in investigating these veins to Mr. O. F. Pattberg and Mr. A. McLintock of the St. Lawrence Pyrites Co.

The ore zones lie in two narrow bands of gneiss of granitic composition which are enclosed in a lens of gabbro. This lens of gabbro has a narrow neck two and one-half miles long connecting it with the boss of gabbro at Pyrites on the N. E. Near the Stella mines this neck is so acidified by pegmatite injection and the effect of granitic juices that it is almost unrecognizable as gabbro. But its continuity with the true gabbro of the northeastern part of the neck proves its gabbroic origin. The lens or boss of gabbro interfingers with limestone on the northeast and pinches out in gneiss of granitic composition towards the southeast.

The acid gneiss which carries the ore may be merely a granitized zone of the gabbro; but it has a very similar appearance to the gneiss which results from the Grenville sedimentary series when they are injected by pegmatite and soaked with granitic solutions. In the latter case these bands would be interpreted as beds wedged apart by the gabbro which was intruded parallel to the foliation.

A generalized structure section drawn approximately to scale is shown in figure 4, the beds dipping towards the N. W.

The upper ore vein on which the Stella shaft is situated is not operated at present. The vein here was worked for a length of 1100 feet along the strike and 900 feet down the dip which varies from 20 degree to 30 degrees, with an average thickness of 10 to 12 feet. The vein in general is enclosed in typical rusty gneiss, which is thoroughly injected with pegmatite. Beginning a little distance above the Stella vein the rock is granite gneiss which is impure with ferromagnesian minerals which are the result of disintegration of a portion of a thin band of overlying gabbro. This gabbro has in turn been acidified by soaking and injection with granitic material and is now of amphibolitic character. The rock immediately beneath the vein is a bluish gray micaceous quartzite underlain by several feet of serpentinized and tremolitic limestone. The latter is barely exposed for a few feet in the railroad cut. The gneiss beneath this is a pegmatitic injection gneiss until the gabbro is reached. The contact between the gabbro and gneiss is not so sharp as might be expected for the gabbro along the contact has been acidified by the granitic solutions and weathers much lighter in color than the main mass.

The lower ore zone is the only one worked, operations being carried on from the Anna shaft. The ore here occurs as a series of veins parallel to each other and to the foliation of the enclosing gneiss. There are four, perhaps five, such veins being worked from the single shaft at the present time. These are called the Z, A, B and C veins going from bottom to top (see section.) Each of the four veins is from 75 to 100 feet above the other. The Z vein has a thickness of from 12 to 14 feet; the A and B veins each average about 18 feet thick, and the C vein is from 6 to 8 feet in width. The veins vary somewhat in thickness reaching a maximum of 40 feet locally on the A and B veins.

The Anna shaft is sunk on the A vein and the workings are down to 600 feet. The veins have been developed along the strike for a length of 1800 feet and have been proved by diamond drilling to extend much further. The strike is N. 45 degrees E. at the southwest end of the vein changing to N. 30 degrees E. towards the N. E. The dip of the veins at the shaft is about 45 degrees N. W. At the northeast end of the veins the dip flattens out in depth to 30 degrees. In tracing the veins along the strike a sharp flexure is found which affects all the veins. The B vein at one place forks and encloses a

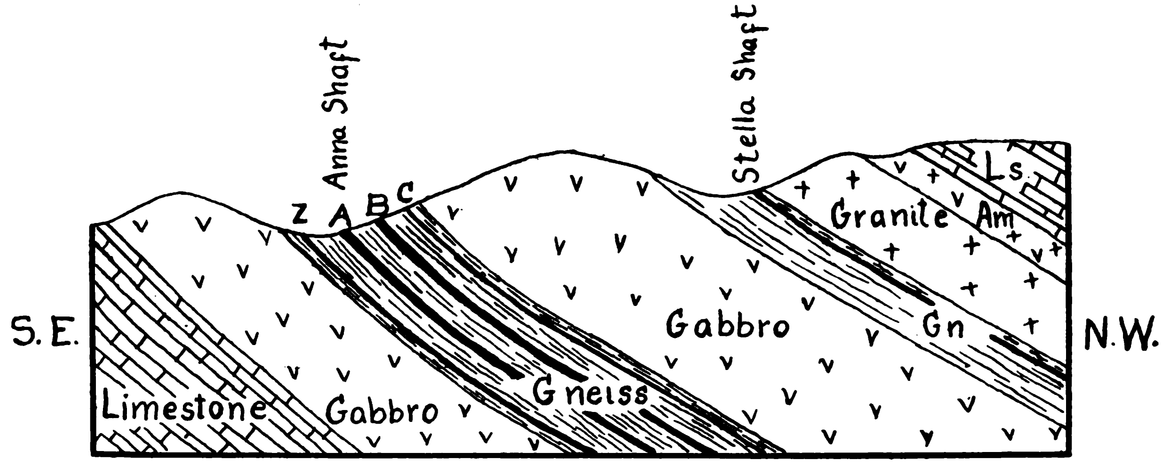

FIG. 4. Generalized Structure Section at Stella Mines.
Am — amphibolite (gabbro soaked with granite)
Gn — Granitic pegmatite injection gneiss.
▬ Pyrite veins.

FIG. 5. Generalized Structure Section at Morgan Mine.

horse of country rock. At the borders of the veins there is a gradation from the typical ore to wall rock impregnated with a little pyrite, but as this gradation is usually abrupt, the veins are fairly well defined. The rock between the veins locally carries some pyrite but in general is fairly clean.

The veins pinch out at the southwest end, in part by becoming leaner and in part by thinning.

The ore consists of a granular aggregate of disseminated pyrite, in part grown together in small bunches, a close irregular network of veinlets of pyrite, and a soft gray alteration product, associated with considerable quartz, some feldspar and fine disseminated flakes of graphite. Smyth has called the soft gray material which is the dominant gangue mineral a chloritic alteration product and when exposed at the surface the gangue of the ore has the typical green color of chlorite. Small bodies of pyrrhotite are met with locally and sporadically. The ore averages about 20 per cent sulphur and is concentrated to 40 per cent sulphur.

Locally the gabbro is pyritized and carries thin layers of granular pyrite a few inches thick, but no pyrite veins of importance have been found in the gabbro itself.

Pyrites

The vein at Pyrites is a thin pyritized zone or stratum within a narrow band or sheet of rusty gneiss which is almost entirely if not wholly enclosed in a boss of gabbro. The geological conditions have been mapped and studied by J. C. Martin who concludes that the rusty gneiss is a member of the Grenville series which has been torn off and included in the gabbro. The vein is exposed almost continuously for three-fifths of a mile along the Grasse River.

Beginning at the north end, it is exposed by a trench and also by a natural cross section on the right bank of the Grasse River three fifths of a mile north of Pyrites, a few yards upstream from the highway bridge. Here, a very good exposure of the vein is afforded in the cliff face on the bank of the river (Fig. 1). The vein is underlain by about 100 feet of strongly foliated and crumpled gneiss, which in turn is underlain conformably by a dark basic chloritized gneiss with abundant flakes of biotite — an altered phase of the gabbro. The rusty gneiss is mostly of a fine-grained bluish gray quartzitic nature with considerable disseminated pyrite; here and there beds with some fibrous mineral — perhaps sillimanite — and a few layers of micaceous serpentinous gneiss. Veinlets of

pyrite cut both the ore and rock approximately at right angles to the foliation. The strike of the vein is N. 40 degrees E. and the dip 60 degrees N. W. The altered gabbro beneath the rusty gneiss only dips 20 degrees to 30 degrees N. W. The vein thins towards the top of the hill, being eight feet thick at the base and four feet at the top. At the top of the hill an excavation 200 feet long and 40 feet deep has been made on the vein parallel to the dip. The vein is eight feet thick at the south end of this cut, thickening to 20 feet at a shaft about 100 feet northeast. The vein is exposed for a length of about 100 yards.

Nearly due south of this exposure, on the left bank of the river, about 60 feet above the stream, the vein outcrops again. An adit has been driven in for about fifty yards on the vein here exposing a thickness of 10 feet. The strike has swung around to N. 34 degrees W. dip 40 degrees N. W. A second adit, a little to the south and above this has been driven a similar distance on the vein. Here there is over 12 feet of ore.

The vein can be followed by several prospect pits along the face of the hill to a point opposite the paper mill where it crosses the river and comes out again on the right bank just south of the mill. The vein exposed in the bed of the river on the left side is very thin and not over two feet thick. It is not certain however that this may not be another vein.

A shaft was here sunk on the vein between the paper mill and river but is flooded and the timber burnt.

About 250 yards south of here is another shaft from which considerable ore has been taken. The vein at the surface is ten feet thick and is separated by only about twenty-five feet of rusty pegmatitic garnet gneiss from the underlying gabbro. The dip is about 30 degrees W.

The next outcrop is at the lower end of the island in the river just below the upper dam. There is a total of only about 50 feet of gneiss exposed here with gabbro both above and below. The vein is at the top of the gneiss with gabbro for the hanging wall. The upstream end of the island is solid gabbro, so that the vein and gneiss both are cut out by the gabbro on this island.

The ore of the vein is much the same throughout. Smyth's description is quoted here. "A specimen of ore from the bed of the river consists of a very fine grained, dark green, chloritic aggregate, with abundant graphite and rather evenly disseminated, irregular masses of pyrite. The thin section shows a quartz-

feldspar, mica aggregate, with cataclastic structure, containing an abundance of graphite, light green chlorite and pyrite."

The following information as to the mine at Pyrites was furnished by H. M. Bradley of Pyrites, formerly superintendent of the Oliver Iron Mining Company, who still hold the property. The mine was first worked about 1886. It was opened by McCray and Murphy in 1905–1906, and the last work was done by the Oliver Iron Mining Company of Duluth, Minn., in 1907. About 900 tons of crude ore were taken out by the latter company, which averaged 22 per cent sulphur and gave about 300 tons of concentrates on milling. The vein was mined down the dip for 250 feet and averaged 16 feet thick varying from 2 to 80 feet.

A–Prospect

A bore hole, No. 100, put in by the St. Lawrence Pyrite Co. about ¼ mile west of Pyrites struck 11 feet of ore fairly rich in large crystals of pyrite at a depth of 94–105 feet. This hole is probably located on another narrow strip of Grenville gneiss which is included in the gabbro. Strike N. 75 degrees W., dip 65 degrees.

B–Prospect

About one mile a little south of west of Pyrites there is a prospect pit on the top of a barren sandy knob. The pit is about ten feet in diameter and excavated several feet in depth. There are only a few other exposures of rusty gneiss, mere skin outcrops. The ore minerals consist of pyrite and pyrrhotite in about equal quantities. Both occur in very irregular branching veinlets averaging one fourth inch, which expand in irregular pockets and bunches. They average several inches apart. The mineral in the pockets is very coarse; crystals of pyrite up to two inches being present. The ore would probably not average more than medium grade.

Ore Bed School

These veins are located near Ore Bed school in the town of Hermon about two miles S. W. of the village of Hermon. They lie in a rusty gneiss which is apparently a portion of the gneiss belt which passes through the village of Hermon. But the gneiss and associated limestones are here all torn to pieces by intrusions of coarse porphyritic granite, and only narrow bands of the gneisses and limestones remain included in the granite.

One such band of gneiss forms the hill on the east side of the road about one quarter of a mile north of Ore Bed school house. This gneiss is the usual injection gneiss. A considerable portion of the band weathers rusty. Along the western border the rock is altered to quartz chlorite schists and the latter are replaced by hematite. There is a flooded pit here from which hematite was formerly obtained. This iron ore and the enclosing schists extend along the west face of the hill near its base.

Within the gneiss there are at least two, poorly exposed, pyrite veins. The strike is N. E. and the dip 45° N. W.

The lower vein is exposed on the edge of a slope 25 feet south of a road which runs along the top of the hill and leads into an abandoned house. It is about two fifths of a mile from the main highway. It is just N. E. of a conspicuous nubbin of deep rusty brown gneiss. The outcrop is only 50 feet long, and deeply weathered, and only locally can anything but a siliceous gossan be found. A thickness of 6 feet of ore is exposed with neither foot wall nor hanging wall visible. The ore is very similar in character and quality to that of the Stella mines.

In a prospect pit at the base of the hill on the west side, about half way between the former outcrop and the highway there is a foot of pyrite ore exposed. This vein lies on rusty gneiss and the top of ore is an erosion surface. The ore is richer than the average and would run 30% sulphur. Other zones within this band are thoroughly impregnated with pyrite.

This band constituting the hill south of the hematite ore pit deserves further investigation. The nearest railway facilities are at Hermon two miles away where a branch line connects with the main line at Dekalb Junction.

Farr Shaft

This shaft is located in the town of Dekalb, about three miles northeast of Bigelow, on the farm formerly known as the Alexander Farr farm now owned by Henry Fleming. It is about one-half mile southeast of the schoolhouse, and the telephone line leaving the road just north of the schoolhouse passes directly over the shaft.

The shaft is now flooded and is reported to have been opened and abandoned in the spring of 1904. The beds of gneiss and limestone, here, together with the ore veins are very seriously disturbed and folded standing in all attitudes with respect to dip.

On the north side of the shaft there is a body of ore exposed lying

almost flat beneath a bed of gneiss with a very gentle synclinal fold The total thickness of ore cannot be seen owing to the flooding of the shaft, but there is 6½ feet exposed, all of which is pyrrhotite except a thin band at the top. This band of ore appears to thin out on the west side of the shaft at the top of an anticlinal fold. On the south side of the shaft a vein of pyrite ore in vertical attitude occurs on the east side. This is about 1½ feet thick and is richer than the average — possibly 30% sulphur. Another vein of ore occurs to the west of this — six feet of gneiss intervening — near water level and could not be investigated. None of the ore is crushed, and fault planes could not definitely be distinguished. Yet the veins seem most certainly to have been affected by the folding.

At a prospect pit 50 yards to the north there is about nine feet of pyrrhotite ore exposed, with the foot wall gneiss dipping 40 degrees, more or less, east.

Limestone lies about 30 feet west of the shaft and the intervening beds of gneiss are vertical. Between the ore vein and the limestone on the east the beds of gneiss are in an intensely compressed and crumpled condition. A big pegmatite dike outcrops about ten yards south east of the shaft.

The total thickness of the rusty gneiss between the limestone beds here is only 200 feet whereas a mile or so to the south west it is about 800 feet thick. This indicates a pinching out of the gneiss at this locality as is actually proved by its absence when an attempt is made to trace it further along the strike.

The gneiss is the usual rusty-weathering pegmatitic Grenville gneiss. The pyrrhotite occurs after a fashion similar to the pyrite at the Stella mines. The pyrite is in a markedly coarsely granular state disseminated in a green chloritic groundmass. An assay of typical specimens of the pyrrhotite ore gave 20.87% sulphur and 0.22% arsenic.

Mitchell Shaft

This shaft is not known locally by any particular name but as it is located on what is known as the old Mitchell farm it is designated by that name here to distinguish it from the shaft to the south west, both of which are on the property of D. G. Styles.

It is located about 2⅔ miles N. E. of Bigelow in the town of Dekalb about two-thirds of a mile S. E. of the road. It is further located on the southeast edge of a small ridge, and lies just north of Indian Creek near the end of Moss Ridge.

A shaft — now flooded to within a score of feet of the top — was

sunk on the ore in the spring of 1904 and then abandoned. There are no means at hand, however, to investigate the vein which is well exposed in the shaft for a depth of about a score of feet. The ore zone is 7 or 8 feet thick. The upper part — 1 to 2 feet — is a sheeted zone with coarse granular pyrite of probably average character. This leaves 5-6 feet of ore through the central part of which there runs a band of pyrrhotite rock from 2½ to 3 feet thick lying parallel to the dip of the vein. It appears to be quite sharply marked off from the pyritic ore above and below. Large blocks of this part of the ore zone are lying on the dump and many merely exhibit a surface tarnished by weathering whereas the pyritic portion is much decomposed. The pyrite ore above and below the pyrrhotite was richer than the average and the pyrite occurs in thin bands parallel to the foliation with thin intervening lenticular seams of chloritic gneiss. In the pyritic sheeted zone at the top of the vein, the rock seems hard, fresh, and unchloritized, the pyrite occurring in irregular veinlets as at the Stella mines. In the hanging wall of the vein thin layers of pyrite occur parallel to the foliation. The wall rocks are the usual bluish gray pegmatitic Grenville gneisses. The foot wall of the vein is possibly about fifteen feet above the limestone beds which outcrop at about that depth below it, the intervening zone being covered. About 200 feet S. W. of the shaft is a small prospect pit partially filled with debris in which only a couple of feet of pyritic ore can be seen. About 35 feet N. E. of the shaft is a small prospect pit in which 7 feet or so of sulphide ore is exposed with a 2 foot band of pyrrhotite running through the center of pyrite ore as at the shaft.

The dip of the vein is about 55 degrees N. W.

The pyrrhotite occurs as a close-woven irregular network of veinlets and bunches of coarse granular pyrrhotite in a very fine grained dense groundmass of pyrrhotite, chlorite, and quartz. The groundmass is so dense as to break with a conchoidal fracture. The coarse pyrrhotite is in veins ⅛ to ½ inch wide. An average sample of the pyrrhotite ore ran 23.48% sulphur and 0.16% arsenic. The whole vein should average 25% sulphur.

Above the vein comes about 400 feet of gneiss which in turn is overlain by limestones. Tourmaline pegmatite veins are abundant in the upper portion of the gneiss. The thickness of gneiss between the limestones here is thus twice that which is present at the Farr shaft. Small narrow outcroppings — as naturally exposed — of gossan occur near the top of this gneiss here and are in the same

stratigraphic position as the vein at the Styles shaft ¾ of a mile S. W.

Styles Shaft

This shaft is located on the farm of D. G. Styles, about 1-4/5 miles N. E. of Bigelow, near the conspicuous elbow of Indian Creek. The shaft is reported to be sunk to a depth of 40 or 50 feet, the ore remaining of the same character with depth. The work was done at the same time — 1904 — as that on the Farr and Mitchell veins and the place has not been touched since.

The pyrite vein as exposed in the shaft is about 9 feet thick. Only a part of this 9 foot zone however is ore, for layers of chloritized gneiss are common as partings in the ore. At one place measured on the north side of the shaft, layers of ore alternate with layers of schist, each varying from a few inches up to a foot in thickness, and the ore layers form less than ½ by volume of the total thickness. On the south side of the shaft there seems to be about 7 feet of ore with several layers of schist aggregating 1½ feet in thickness. A pegmatite lense practically unpyritized occurs in the upper portion of the vein. The richness of the ore is rather variable but would average up to a medium grade. The pyrite in the richer streaks is of markedly coarsely granular disseminated character.

The wall rock is the usual rusty pegmatite Grenville gneiss. The hanging wall is formed by about 10-15 feet of finely laminated gneiss intervening between the vein and overlying limestones. The footwall is similar gneiss. Smyth reports limestone as underlying the gneiss. The writer could not find this and if it is present it must be a mere bed in the gneiss. The gangue mineral is the usual greenish chloritized gneiss with disseminated graphite.

The strike of vein is N. E. and the dip about 35 degrees N. W. The vein is covered by drift along its strike.

Hendricks Shaft

The Hendricks shaft is located in the town of Dekalb, 1½ miles S. W. of Bigelow, on the west side of the railroad where the latter crosses Boland Creek. The lease is now held by J. H. McLear of Gouverneur.

The shaft — now flooded — was sunk about fifty feet on the ore vein which here varied from 1½ to 2½ feet thick with an average of two feet. The ore of this band is reported by Robert Love of Richville who sank the shaft to have run 30% Sulphur. The ore is

even grained, coarsely granular, disseminated in a chlorite gangue. The ore vein has been traced by trenching and prospect pits for a length of a hundred yards. At the northern end, immediately beneath the railroad track, the vein widens to six feet. This ore vein is but a richer band lying in a pyritic zone which is well exposed in the bed of the brook where it is about ten feet thick.

Here, limestone is exposed as the foot wall of the gneiss belt. It is overlain by 7-10 feet of chloritic gneiss with a fresh pegmatite vein from ¼ feet thick at the base. The rich ore vein about two feet thick overlies this gneiss, and is in turn overlain by 0.8 foot of lean gneiss. This is succeeded by two pyritic sheeted zones each about two feet thick and each separated from each other by about 2½ feet of chloritic gneiss with only a rare thin layer of pyrite. In the sheeted zones the veins are from ¼ to one inch thick averaging about one half inch and form from one third to one seventh of the total rock by volume. These thin layers or lenticular pockets are parallel to the foliation and consist of coarse granular pyrite. The lower sheeted zone might pass for lean ore but it is doubtful if the upper zone carries a sufficiently high percentage of sulphur or a convenient position to warrant mining.

The wall rock of the vein is a muscovite gneiss of granitic composition, almost schistose in appearance. Owing to the abundance of the muscovite scales along the foliation planes and the finely laminated character, the rock resembles a muscovite schist. It represents original Grenville sediments injected, disintegrated, and recrystallized by pegmatitic injection. The rock of the sheeted zones is hard and comparatively unaltered and fresh. The gneiss here is similar to that met with in the Kilburn belt to the southeast. The dip of the vein averages about 70 degrees N. W.

Cole Mine

The Cole mine is located beside the railroad on the farm of J. Frank Cole, 5 miles N. E. of Gouverneur.

The mine has been recently leased to the St. Lawrence Pyrites Co. who began development work the past summer. Preparations to unwater the mine were in progress at the time of the writer's visit and shot drilling was being carried on on the company's property adjoining the Cole farm on the N. E. Numerous pits several hundred feet S. S. E. of the shaft have uncovered good exposures of pyrite much richer — by at least five per cent or more — than the ore at the Stella mines.

The last firm to operate the mine was the Hinckley Fiber Co. which took out considerable ore to use in making sulphurous acid for a sulphite pulp process in connection with its paper mill.

Pyrite ore is exposed both at the shaft and again by prospect pits several hundred feet south S. S. E. of the shaft.

The following data were given by W. J. Bulger of Gouverneur. The shaft was sunk 225 feet on the ore at an angle of 26 degrees parallel to the railroad which is here N. E., making the strike N. W., a very unusual phenomenon for this district. The ore vein on which the shaft is sunk ran from 15-18 feet in thickness. A second body of ore was struck by crosscutting to the northeast for about 15 feet through the gneiss. A drift was run through this body for 90 feet parallel to the railroad while a drift at right angles to this was cut through ore for 60 feet, coming against limestone on the northwest and gneiss on the southeast. The vein on which the shaft is sunk and this overlying ore body were found to be connected by about ten feet of ore on the northwest side. The ore here has evidently been folded together with the gneiss subsequent to its formation and the apparent size of the upper vein is probably due to the flat lying position. At the southeast end of the pit, the ore vein suffers a sharp pinch together with the gneiss.

The prospect pits, seven in number at the time of the writer's visit, to the southeast have exposed ore which is richer on the average than that at the Stella mines and will run 25% or more of sulphur. Here too the structure of the veins is very complicated. The southern part has a normal N. E. strike for an exposed length of a hundred feet. It then turns sharply and trends in the direction of the vein at the shaft. It is impossible to ascertain the dip because of the variable dip of the banding of the pyrite, locally being very gentle and locally vertical. This also prevents an estimate of the actual thickness of the vein as exposed in these pits. The width of the ore exposed is about 30 feet.

The ore here is of a different type from any of that encountered elsewhere. It is conspicuously banded and varies from fine to very coarse loosely granular in thin alternating layers. The ore is prevailingly fine to medium grained with a narrow band one half to one inch thick of coarse material every few inches. These coarser bands are purer and the grains of some of the pyrite are occasionally an inch in diameter or more. Thin lean bands of gneiss are also found. The gangue is a pale greenish gray material which appears to be an alteration product of the gneiss which it is replacing. The

wall rocks of the pyrite veins both at the shaft and in the prospect pits is the usual rusty gneiss. At the pits it is considerably chloritized adjacent to the vein and contains an occasional veinlet of pyrite. The contact between ore and rock however is quite sharp.

Caledonia

The Caledonia mines are located just east of the Old Iron Works in the town of Rossie. They were formerly worked for hematite and the cuts made in pyrite rock were incidental.

About 225 yards east of the Old Iron Works road intersection, a narrow band of rusty gneiss outcrops on the road. Scattered outcrops of pyritic material occur in the road and south of the road, but they are so few and so poorly exposed that little information can be gained. The rock seems to be a pyritized altered sheeted zone of gneiss some of which would pass for ore.

About 75 yards south of here a prospect pit in hematite crosses a pyritized sheeted zone which is unusually pyritic for the average rusty gneiss, but is too lean for ore. A sheet of hematite overlies the pyritic zone and veins of hematite have replaced the latter downwards along fissures. The strike here is N. E. and the dip 25 degrees N. W. whereas the strike at the shaft a couple of hundred yards west is steep east. The beds here have suffered considerable disturbance, and the conditions are favorable for good ore veins. But the Grenville schists and gneisses here are so covered by a capping of many remnants of Potsdam sandstone and obscured by glacial drift that prospecting by drill would be necessary. Conditions are favorable for this purpose.

Keene Ore Bed

This property is located about one third of a mile west of Keene's Station in the town of Antwerp. It is part of the Keene estate and information can be obtained from George Partridge, New York.

The mines were formerly worked for hematite, now abandoned. Considerable pyrite, along with rock, forms a large dump beside the road. The pyrite ore was probably struck in the workings beneath the Potsdam sandstone. The place from which it was taken was not found. An exposure of similar pyritic ore however occurs at the S. E. end of the mine at the top of the S. E. face of the hill. A shallow excavation in the pyrite ore here shows about 9 or 10 feet of ore, the vein dipping about 45 degrees N. W. Strike N. 65 degrees E. Neither top nor bottom of the ore is exposed.

The vein is in rusty gneiss and can be traced a hundred yards along the strike to the S. W. The rusty gneiss here forms the upper part of a series of quartz-chlorite schists which are the result of alteration and replacement of the usual pegmatitic garnet-biotite gneiss which outcrops several hundred feet away. The hanging wall of the pyrite vein is exposed here but the foot wall is covered. About fifty feet of rusty gneiss are exposed overlying the quartz chlorite schists. Toward the N. E. the vein passes beneath the old workings for hematite which are beneath a capping of Potsdam conglomerate. The vein undoubtedly has a further extension in both directions.

The ore is of similar character and quality to that of the Stella mines, and to that of the Morgan mine to the S. W.

The prospect is located only one fifth of a mile from the railroad and a power line crosses the property. Conditions seem very favorable for the finding of good ore and the property deserves investigation.

Morgan Ore Bed

This property is located in the town of Antwerp 1½ miles S. W. of Keene's Station. It is an old abandoned iron mine and was formerly known as the Morgan or Pardee ore bed. The cut in the pyrite is about 100 feet west of the highway. The ore lies in a series of chloritic schists which towards the west are overlain by a bed of Potsdam beneath which they are locally replaced by hematite. A hematite vein crosses both the dip and strike of the pyrite vein. It was for this hematite that the cutting or trench was made, incidentally exposing the pyrite. The strike of the hematite vein is N. 75° W. and the dip approximately vertical, whereas the strike of the pyrite vein is N. 40° E. and the dip 25° W. The hematite vein is about three feet wide and is exposed by an open cut for a depth of ten feet and length of fifty feet. The hematite is the result of the replacement of the pyrite rock along a fracture. The vein walls are perfectly fresh, and the vein grades into the pyrite rock through walls of chlorite schist. It also contains disseminated graphite.

There is about eight feet of pyrite ore exposed with neither hanging wall nor foot wall visible. The vein weathers with a coarse pockety appearance due to the presence of richer and leaner streaks and lenses of ore. Narrow veins of pyrite with a quartz gangue up to several inches wide occur along fractures.

An analysis of several speciments taken from different parts of the vein gave 23.24% of sulphur.

Wight Ore Bed

This property locally known as the Wight Ore Bed is located in the town of Antwerp about two miles north of the village of Antwerp. The mineral right is now held by Robert Dickinson. Several prospect pits were put in for hematite here but there was no extensive development such as was carried on at the other mines.

The pyrite vein lies in a band of rusty gneiss which forms a hill somewhat over twenty feet high and a thousand feet long. There is a total thickness of about 250 feet of rusty gneiss exposed here with a foot wall and a hanging wall of quartz-chlorite schists locally replaced by pockets of hematite. The whole zone of rusty gneiss is more highly impregnated with pyrite throughout than usual. The rusty gneiss is of the usual Grenville character. At the south end of the hill a 75 foot pegmatite dike intervenes between a hematite bed and the gneiss. The dike adjacent to the hematite is considerably altered and chloritized. About 125 feet N. E. of this dike there is a lens of amphibolite with abundant minute garnets, considerable disseminated graphite and a rusty weathering surface. Rock of this character forms the east half of the hill at the north end.

About 400 feet N. E. of the south end of the hill is a prospect pit ten feet deep which together with exposures at the top indicate a thickness of 18 to 20 feet of pyrite, dipping at about 45° N. W. and striking N. 19° E. The vein is proved by several small pits towards the south for a length of 400 feet. At the north end of the hill the beds swing around to the N. W. and several feet of good ore similar to that to the south is exposed there. In addition there is about 20 feet of ore of different character which appears to overlay the main vein. This ore consists of dark chloritic gneiss with abundant disseminated medium grained pyrite grains.

The pyrite of the main vein occurs for the most part in a network of veinlets, developed on a coarse scale and which carry more very coarse pyrite than any other prospect except that of the Dickinson mine to the south. Crystals from one half inch to one inch are very abundant. This coarse granular pyrite also occurs in irregular bunches up to several inches in diameter. On the other hand the gangue between the veins is lean and is developed on as equally coarse a scale as the veins so that the average sulphur content of the rock is probably about 25%. An analysis of fragments from several blocks thrown out from the prospect ran 28.3% sulphur. The gangue is the chloritized gneiss which the pyrite is replacing, consisting of quartz, feldspar, and chlorite.

This prospect is the most favorably situated and exposes the best showing of good pyrite ore of any undeveloped properties seen.

Dickson Ore Bed

This property is located in the town of Antwerp about a mile and a half north of Antwerp on the Jefferson Iron Co.'s switch. Considerable hematite was taken out here, but the shafts and pits are now abandoned and flooded. No prospecting for pyrite has been done here.

About 100 yards north of the junction of a short spur with the main switch here, there is an exposure of pyrite ore. The vein as exposed is about 30 feet across, the underlying schists dipping 30 degrees west while the overlying schists dip 50 degrees west. This probably indicates a thickness of at least 15 feet of ore. The ore is a trifle less coarse than that of the Wight prospect but of the same general character. There are abundant irregular pocket-like aggregates of coarse granular pyrite with a veinlet network of finer grained pyrite. The vein is exposed northward along the west face of a small ridge for a length of 400 feet. At the north end of this ridge the pyritic gneiss forms a narrow band between walls of chlorite or quartz chlorite schists. The great thickness of rusty gneiss visible at the Wight prospect is absent here. The pyrite vein is underlain by about 40 feet of schist which overlies a bed of hematite about ten feet thick on which a shaft has been sunk. The overlying schists also carry hematite veins especially where they underlie a remnant of Potsdam sandstone.

About 1000 feet south of this exposure of the vein there is another outcrop of pyrite ore exposed about 25 yards east of the railroad track. There is five feet of pyrite ore exposed here with neither foot nor hanging wall visible. The strike of the vein at the northern outcrop would carry it above this vein here and it may be that this is another vein and not the continuation of the one to the north. On the west side of the railroad a shaft has been sunk on a hematite bed in the chloritic gneiss overlying the pyrite vein. A remnant of Potsdam sandstone would overlie the continuation of the northern pyrite vein if it is a different one from that here exposed.

Laidlaw Farm

This property is located on the west face of a conspicuous knob-like hill (Fig. 6) about 60 feet high, one mile S. E. of Oxbow and one fourth of a mile S. W. of the road to Antwerp, on southwest

side of Creek. The western face and the crest of the hill is formed by a band of deep rusty gneiss whose dip is only a trifle steeper than the slope of the hill. This pyritic gneiss band is about fifty feet thick with the hanging wall covered and the foot wall formed by several hundred feet of garnet-biotite gneiss enclosing an occasional narrow band of amphibolite. This gneiss is the usual type of injection gneiss of granitic composition belonging to the Grenville series. It is probably underlain at the base of the hill by limestone. A narrow valley in which all outcrops are covered lies between the hill and the steep cliff faces of coarse red porphyritic granite about 100 yards to the west. The basal portion of the beds underlying this valley may be rusty gneiss but the remainder is probably the injection gneiss which appears along the line of strike farther south.

The rusty gneiss is simply the oxidized and weathered outcrops of a pyritized phase of the bluish gray gneiss which constitutes the country rock, although local beds seem more like true quartzites.

The strike of the beds at the south end of the hill is about N. 15 degrees E. and the dip 40 degrees west while at the north end the strike swings around to N. 20 degrees W. and the dip flattens to 25 degrees W. If this belt of gneiss is followed farther it is found to turn rapidly to the west, and wrap completely around the north end of the mass of porphyritic granite gneiss, thinning as it goes, and to run for a short distance as a very narrow band southeast along the northwest side of the granite mass until it is completely cut out by the granite; the latter then coming directly against the limestone.

The ore zone occurs at the top of the exposed band of rusty gneiss lying along the whole western flank of the hill. Development work is reported to have been undertaken in hope of finding gold. At the southern end of the hill a shaft has been sunk on ore to a reported depth of 20 feet. At the north end there is a prospect pit in which nothing can now be seen. The really best exposure of the ore is about 150 feet south of the shaft. Here there is an outcrop about 50 feet long showing a total thickness of about 22 feet of ore. The upper 18 feet is pyritic ore the pyrite being quite irregular in its distribution. Much of the ore is rich although lean streaks are present. Much of the pyrite is in abundant small pockets and coarsely granular veins. The ground mass is of green chloritic gangue and fine to medium grained pyrite. The whole would give at least an average content of sulphur, that is, 20% and probably more.

The lower four feet of the ore zone is pyrrhotite which is better exposed in the shaft than here. The shaft is flooded, but there is

from 7-10 feet of pyrrhotite ore exposed here between the foot wall and an overlying rich pyrite band. The pyrrhotite ore consists of fine-grained granular pyrrhotite in a gangue of chlorite and altered gneiss with narrow veins up to one half inch in width of coarse granular pyrrhotite intergrown with some pyrite. There are two feet of very rich pyrite ore overlying the pyrrhotite in the shaft without the hanging wall being exposed. The ore at the shaft here is overlain by a rusty brown highly ferruginous glacial drift with a low angle of dip to the west. The cementation of the drift has probably taken place by solutions which leached the iron from the pyrite beds above.

If the pyrrhotite at the shaft is the continuation of the pyrrhotite in the outcrop at the south, then only the basal portion of the pyrite ore of this exposure can be seen at the shaft, and the rest of the pyritic vein should lie under the covered zone immediately at the base of the hill. The vein is exposed for a length of about 200 yards and a bare rusty zone of earth indicates its extension beneath the surface for considerable distance further towards the northwest. The vein at this end turns rapidly towards the west and is probably cut by the granite mass at some distance in this direction. The vein cannot be traced to the south and does not appear in the extensive gneiss exposures a quarter of a mile south. The rusty gneiss is probably a narrow lenticular band carrying the mineralized ore zone of pyrite and pyrrhotite and attaining a minimum length of a thousand feet, dying out towards the south, and towards the north curving around to the west and there cut out by the granite.

A rough average sample of the 7 feet of pyrrhotite exposed in the shaft obtained by selecting half a dozen specimens from different parts of the vein gave 27.78% Sulphur. A sample of the rich two foot ore zone above the pyrrhotite at the shaft ran 29.06% sulphur and 0.22% arsenic.

Frank Bent Farm

This prospect is located in the town of Antwerp on the farm of Frank Bent 2½ miles southwest of Oxbow about ¼ mile southwest of the "Pulpit Rock" road and near some old iron ore pits. It is just about opposite the fifth farmhouse after leaving Oxbow on the "Pulpit Rock" road.

There is a long narrow valley here running N. E., with the porphyritic granite gneiss forming the southwest wall, and limestone with a narrow belt of schist capped by Potsdam sandstone forming the northwest wall. The schist is for the most part a chloritized

and much altered gneiss. A narrow band of the schist has been more or less replaced by hematite on which considerable prospecting has been done.

A small shoulder or spur juts out into the valley here from beneath the Potsdam and is formed of rusty gneiss. This is conspicuous because of the bare rusty brown outcrop. There is a total thickness of 50 or 60 feet of rusty gneiss exposed here, neither base nor top being in evidence. The gneiss is the usual type with garnet, biotite, and graphite as accessory minerals in addition to the quartz and feldspar. The gneiss is crumpled, flexed, and considerably broken up. It is standing in a very steep to vertical attitude.

The ore zone is in the central part of the rusty gneiss and is twenty-five feet thick. In about eight feet of this ore zone the pyrite occurs in nodules of fine grained granular pyrite with a little green chloritic gangue. This rock weathers with a pebbly nodular appearance, the irregular pyrite bunches averaging from 1/4 inch to an inch in diameter. Some of the nodules are several inches in diameter and are formed of alternating concentric shells of pyrite 1/8 inch in thickness and thinner shells of green chlorite. The remainder of the ore has a very marked narrow banding and constitutes a pyritic sheeted zone. The alternating bands of rich and lean ore average from 1/8 to 1/4 inch in thickness and are fine grained granular. The ore itself shows plications and intense disturbance the same as the enclosing gneiss. A prospect pit was started here but merely went a few feet into the ore next to one wall. The ore is exposed here for a hundred feet and passes southwest beneath a capping of Potsdam sandstone. In the valley to the east, the ore vein can be traced by several outcrops of rusty gneiss which are overlain by a few feet of ore for a distance of a hundred yards. The beds dip steeply west and are highly disturbed, having a trend a little north of magnetic east. At the furthest outcrop in the valley about four feet of the rich nodular ore overlying rusty gneiss is exposed. The full thickness of the ore zone is not exposed in the valley but there are strong indications that a much greater thickness than the few feet actually exposed is really present. In the valley here, a narrow wedge of granite which pinches out to the northeast, lies between the rusty gneiss and limestone. The total length of vein exposed is 400 feet. There is no reason evident why it should not extend up the valley for considerable distance to the northeast, and also extend beneath the Potsdam along its line of strike. Whether it is the same vein as that in the limestones 1/2 mile to the north is a question which cannot be answered with the present data. If so, then the unusual

width and thickness of the vein here may perhaps have some relation to the folding and disturbances which the gneiss here has suffered.

An analysis of the average of several specimens taken from the vein gave 22.15% S so that the entire thickness (25 feet) of the vein taken as a whole would appear to be of average quality.

Pyrrhotite-Pleasant Valley School

This prospect is located in the town of Edwards, on the east side of the road opposite a sawmill about three tenths of a mile north of Pleasant Valley School.

The pyrrhotite lies in a narrow band of rusty gneiss which pinches out to the southeast. The latter is about 250 feet thick here lying between limestones. Part of the gneiss is the usual rusty weathering garnet-biotite gneiss, but part is either a silicified phase of the gneiss or else a quartzite. The pyrrhotite vein occurs in a lens of this siliceous rock about 100 feet wide. Pegmatite veins are abundant in the quartzose mass. The pyrrhotite is exposed only in the pit surrounding the flooded shaft. There are two masses of the pyrrhotite separated by a wedge of coarse vein quartz. The two masses come together at the shaft. One vein is six feet wide at the N. E. end and is exposed for a length of 20 feet to the shaft where it is ten feet wide. The other vein is five or six feet wide at the north and is exposed only for a length of eight feet or so to the shaft where it joins the other. The continuation of this mass cannot be traced beyond the pit in any direction and it is probably only a lense. The pyrrhotite is unusually pure and consists of a very coarse granular aggregate of pyrrhotite with only a trifle quartz as gangue. It is almost solid pyrrhotite with here and there a grain of pyrite. Among the specimens on the dump some are found which are crossed by fine veinlets of galena. A narrow pyrite vein also crosses the pyrrhotite. This deposit is of different type from any other seen by the writer, in its association with vein quartz and the absence of chlorite.

About a mile N. E. of here, along the line of strike, and near the contact of the limestone and gneiss there is a prospect pit just south of the road. There has been a very considerable quantity of highly ferruginous rusty drift thrown out from this pit but no bed rock was visible. The iron cemented drift is similar to that overlying the gossan of pyrite veins at other localities and may mark the site of an underlying lens of pyrrhotite or perhaps pyrite here.

Just to the N. E. of this pit there is another excavation located on the bank of the river. This prospect has only been sunk several feet in the bed rock and the walls of sand had slumped in and covered most of the rock. The stuff on the dump showed blocks of bluish quartzite, limestone with pyrite veins, and a few blocks of pyrite up to one foot in diameter, apparently the maximum width.

This is the only occurrence found where the pyrite veins were in limestone. They are probably of similar type to the zinc veins of the Edwards district.

New York State Defense Council

BULLETIN No. 2

THE ZINC-PYRITE DEPOSITS OF THE EDWARDS DISTRICT, NEW YORK

By DAVID H. NEWLAND

(PRINTED BY ORDER OF THE COUNCIL)

November, 1917

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HON. CHARLES S. WHITMAN, *Chairman,*
State Defense Council
Albany, New York.

SIR:—The immediate requirements of our industries for pyrite supplies have led to additional surveys of the recently opened zinc field in the Edwards District of St. Lawrence County where these two important minerals, zinc and pyrite, occur in association and, as this report indicates, both in quantity adequate to greatly increase development.

The accompanying report on these mineral supplies is therefore submitted as appropriate to the work of the State Defense Council.

VERY RESPECTFULLY SUBMITTED

JOHN M. CLARKE
State Geologist
Chairman of Geology,
National Research Council

THE ZINC-PYRITE DEPOSITS OF THE EDWARDS DISTRICT, NEW YORK

By David H. Newland

INTRODUCTION

The information hitherto available concerning the Edwards zinc deposits has been rather meager, hardly commensurate with their standing from a commercial viewpoint or with their interest from the geological side.

Mather[1] made cursory note of the occurrence of sphalerite in the Edwards district as far back as 1838, but the deposit to which he refers had been opened for lead rather than zinc, which at that time found little employment. No mention was made of any other occurrence in the district.

In 1906 Newland[2] published notes on the deposits near the village of Edwards which shortly before had come under prospect and development, and also gave some account of the abandoned workings near Sylvia Lake. A more extended description by the same writer[3] appeared in the "Engineering & Mining Journal" of that year.

In 1913 McDonald[4] briefly described the Edwards mines then developed to a point which warranted the inauguration of active production. Operations were delayed for two years, however, by the problems encountered in the milling of the ores, complicated perhaps by the policy pursued by the company of saving the pyrite as well as the blende.

The geology of the ores was discussed for the first time in a contribution by Newland[5] to "Economic Geology," wherein also was given some account of the physical and chemical characteristics of

[1] Geology of New York: Report on Second District, Assembly Doc. 1838, No. 200, p. 213.

[2] The Mining and Quarry Industry of New York state. N. Y. State Mus. Bull. 102, 1906, pp. 157–159.

[3] Engineering and Mining Journal, Vol. 81, p. 1094–5, 1906.

[4] Idem Vol. 95, p. 363, 1913.

[5] Econom'c Geology, Vol. XI, No. 7, Oct–Nov. 1916.

the ores and their probable origin. The bodies were recognized as replacements of the Precambrian limestones in which they occur and as having been formed at considerable depths following the metamorphic process which led to the silication of the limestones.

The present contribution deals more particularly with the geology and economic development of the deposits. In the study of the origin of the ores — which is no less of interest and importance in view of the rather unusual conditions of their occurrence — the cooperation of C. H. Smyth, Jr., had been enlisted and a separate chapter had been nearly completed by him for inclusion with the report. It is regretted that owing to the exigencies of time and space the publication of this part must be postponed to a later date.

In the study of the general geology of the district the assistance of Dr. Cushing, who for the last two seasons has been engaged in the mapping of the Gouverneur sheet in which Edwards lies, has been of material advantage. It is unfortunate that the areal map can not be referred to in connection with the descriptions; although nearly completed, so far as field work is concerned, its publication can hardly be expected before another year or two.

Acknowledgment is due to many of those interested in the mining industry of northern New York for information and other aid rendered in the work. To T. M. Williams and J. H. McLear the debt is particularly important. In visits to the mines of the Northern Ore Company, many courtesies have been extended by the former and present members of the company's staff, including A. J. Moore, Justice Grugan, Cecil Pocock, G. S. Patterson and W. D. Blackmer.

HISTORICAL

The first shipments of zinc ore and pyrite from Edwards in a commercial way were made in the spring of 1915, with the beginning of regular mining operations by the Northern Ore Company on its property just outside of Edwards village. The record of the discovery and development of the deposits, however, covers a considerable period anterior to that date.

The earliest mention of zinc in connection with the Sylvia Lake-Edwards limestone belt that the writer has been able to find is contained in one of the preliminary reports of Ebenezer Emmons[1] relative to the progress of his survey of the Second District of New

[1] Geology of New York: Report on Second District, Assembly Doc. 1838, No. 200, p. 213.

York. He refers to the occurrence of zinc and lead on the Balmat property in the following words:

"In the town of Fowler, a remarkable vein of the sulphurets of zinc, lead and iron, in about equal proportions, occur on the farm of Mr. Belmont.[2] The direction of the vein is n. n. e. and s. s. w. and the width about eight inches, but not well defined. These sulphurets traverse a bed of serpentine 40 to 50 feet wide. The occurrence of zinc intermixed with lead, is not favorable to the reduction of the latter."

In a further paragraph of the same report Emmons expresses the opinion that mining on the Balmat vein will not prove profitable. It is apparent from the wording that the deposit had already engaged attention from prospectors, and no doubt some of the development work evidenced by the shaft and tunnel openings that exist at present traces back to this early period. The purpose of the operations evidently was to prospect for lead, rather than zinc which at that time would hardly have been considered an element of value in the ore. It is likely that other deposits in the district were uncovered at about the same time.

The Streeter property which adjoins the Balmat on the north, across the road, contains prospects and dumps situated along a band of ore that bear evidence of having been made years ago and some of them may be contemporary with the early operations already noted. There are no further records relating to the district, however, for the interval of about 75 years preceding the present developments.

In 1903 T. M. Williams who was then engaged in mining work near Gouverneur had his attention called to the uncovering of zinc ore on the Todd farm, a part of the properties now under operation. It appears that the limestone ridge in which the ore occurs had been cut into for the purpose of quarrying road material and the edge of the ore zone thus exposed. Mr. Williams visited the place and recognized the possible importance of the discovery. The property, as well as the adjoining Brown tract was taken over, under lease or purchase, by Mr. Williams in association with the Northern Ore Company who then began systematic prospecting work which continued for a year or more. In 1905 operations were suspended on account of legal entanglements and were not again resumed until some five years later. A period of experiment

[2] The name is properly spelled *Balmat*.

with the concentration of the ores and of mine development followed, so that nothing more than trial shipments were made until early in 1915 when the mines were placed in steady operation. The present mill is the second on the property, the first having been destroyed by fire as it was about ready to run. The process of mill treatment is rather novel for zinc ores, being a combination of gravity and magnetic separation, whereby both the pyrite and zinc-blende are recovered. The more common practice in dealing with pyritic blende is to subject the ore to a preliminary roast, with the view to changing the iron sulphide partly into magnetic form which then is followed by magnetic separation, with loss of the sulphur value represented by the pyrite. The need for experiment with the new process was responsible for some of the delay in starting production.

The establishment of this enterprise on a settled basis naturally has served to awaken interest in the field at large, and prospecting has been quite active in the last year or two. The results have been encouraging in so far as the uncovering of new deposits is concerned, for the known occurrences have been increased from four or five to a dozen or more. It is not possible as yet to estimate the economic importance of those discoveries which are still in the prospect stage. It seems quite probable, however, in the light of the results obtained at Edwards, that the district has possibilities for further growth by the development of additional ore bodies which can be profitably worked. It seems equally certain that the contribution to be expected from all sources will not be very large measured by the outputs of some of the western fields; but with ores of the grade now produced or revealed on the surface and with the advantages of economic mining that are offered the district has its own attractions which will gain recognition.

The zinc ores of the Edwards district it may be well to note, have little or nothing in common geologically with lead-zinc deposits that occur in the Grenville limestones and schists to the west of Gouverneur which have been studied and described by C. H. Smyth, Jr.[1] The latter are true veins formed by the filling of fissures which intersect the limestones and adjacent formations extending upward into the Potsdam sandstone. They are evidently the work of ground waters, rather than deep seated circulations. They carry more galena than blende, with a gangue of calcite. These deposits were the object of considerable mining activity

[1] "The Rossie Lead Veins," School of Mines Quarterly Vol. XXIV, 1903.

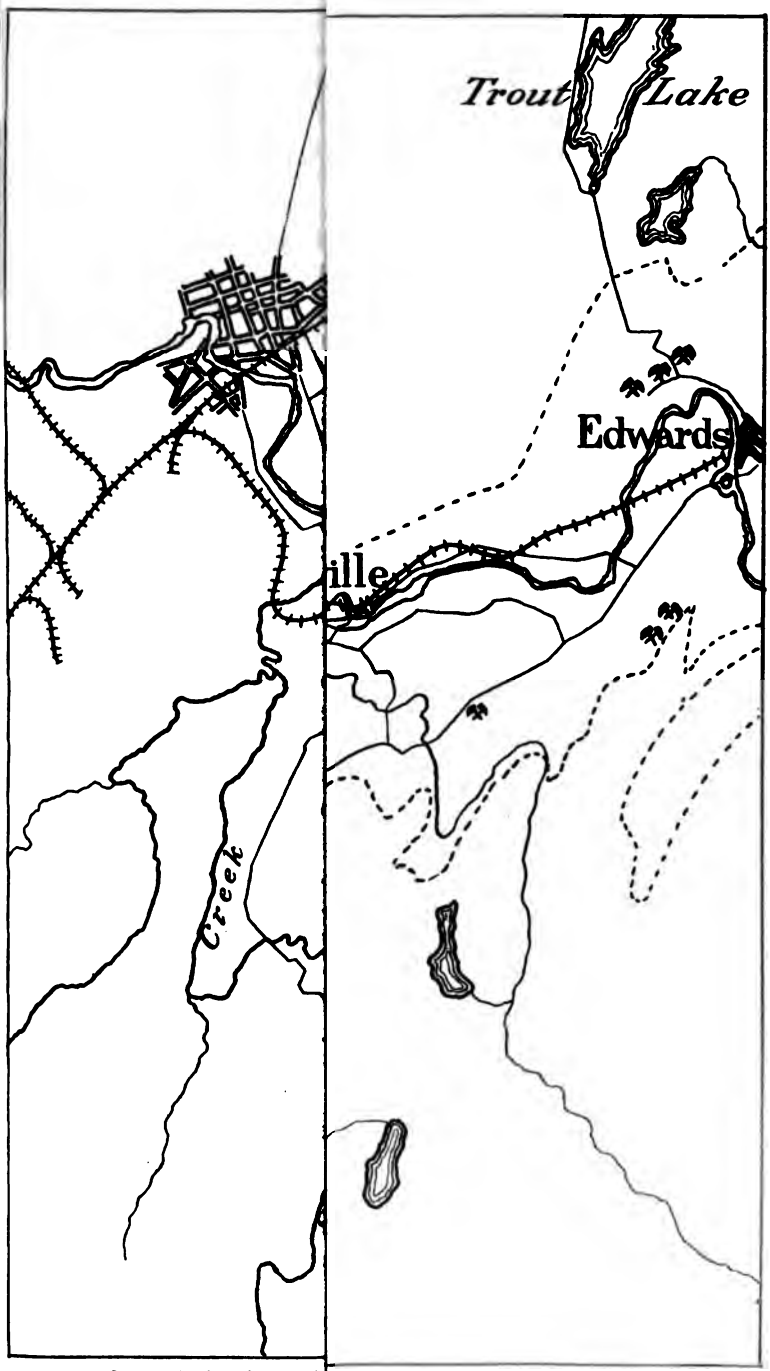

Fig. 1. General sketch of th hammers). The minor belts of schists

about the middle of the last century and have been worked in a desultory way in more recent years; they are too small generally to afford a real basis for the production of lead or zinc, although they may come near to the economic limit in one or two instances. Among the different localities where the lead-zinc veins occur may be mentioned the Victoria (Pardee) and Lead Hill mines in the town of Rossie; Mineral Point; and the Pennock, Downing, Turner and Clute farms in Macomb. Just north of Redwood, Jefferson county, there are veins that intersect both Grenville limestone and the overlying Potsdam, which demonstrates their relatively recent origin, as compared with the zinc-pyrite deposits of the Edwards district.

PHYSICAL FEATURES

The Edwards district lies on the margin of the Adirondacks in southern St. Lawrence county, a region of rugged rocky ridges but not really mountainous in character. The elevation in nowhere over 1000 feet and the general average is from 600 to 800 feet, the lowest points being within the limestone valley which constitutes the district proper.

The district is reached most conveniently from Gouverneur, a prosperous village that has long been identified with the marble and talc industries and is the chief commercial center of this part of St. Lawrence county. A branch of the Rome, Watertown & Ogdensburg railroad extends east from Gouverneur to Edwards village in the northern section, where the principal mining operations are now in progress.

Altogether the district, as defined by the outcrop of limestone, covers an area of over 20 square miles in the form of a rather irregular belt that has a northeast-southwest axis parallel with the general structural trend of the region. The belt averages from one to two miles wide. On the southwest it terminates abruptly in a broad curve that sweeps around Sylvia Lake which occupies a basin in the limestone. Toward the northeast the limestone can be followed uninterruptedly to Edwards and even beyond that village, as indicated by the outlines drawn on the accompanying sketch map based on the Gouverneur and Harrisville quadrangles of the U. S. Geological Survey. The southern margin of the belt is very irregular, with the limestone forming deep indentations or embayments in the gneiss country and near Fullerville sending off a band which extends south up the valley of the West Branch so as to join, probably, with the parallel belt southwest of Harrisville.

The surface features of the limestones contrast with those of the bordering hard formations, having smoother more open contours. The limestone outcrop for the most part forms a well marked valley, the larger part of which is drained by the Oswegatchie river. The two main branches of the stream enter the valley from the south at points several miles apart and after a converging course unite on the northern margin at Hyatt. After their confluence the river flows out of the valley, crossing the gneiss country in a narrow channel broken by waterfalls to the next belt of limestone around Gouverneur.

A survey of the topographic features leads to many interesting deductions about the drainage which need not now be set forth further than to say that the valley antedates the present river system, tracing back to preglacial time when it was occupied by a stream that followed a longitudinal course, rather than transverse to the belt of limestones as at present. The old rock floor of the valley is largely masked by glacial and alluvial deposits.

In its geology the district belongs to the Adirondacks, quite as much as if it were somewhere in the interior instead of on the margin of the highland. The elevations alone characterize it as part of the bordering foothill area. Instead of an altitude of 1500-3000 feet which prevails in the interior, the limestone belt is mostly comprised within the limit of the 700 foot contour, and the surrounding ridges rise scarcely 200 feet higher. The relief accordingly is quite moderate, though in parts the surface is rough, particularly within the country occupied by the harder granite and gneiss, much of which is a wilderness traversible only on foot, with numerous swamps and lakes in the lower ground.

The surface as it now appears to view is the outcome of a complexity of conditions and processes in the sequence of which the glacial invasion already alluded to occupies a rather recent place. To decipher the record of the many changes that have taken place it is necessary to seek information beyond the confines of the district itself. Broadly speaking the physical history of the area is identified with that of the larger Adirondack province of which it constitutes a part. The task of description is thus greatly simplified by the work that has been done elsewhere in the Adirondacks and especially by the recent investigations of Cushing, Smyth and others in the western area.

Precambrian peneplain. The uniformity of elevation of the harder ridges that surround the limestone is one of the striking physical features which require explanation. If we stand on a

ridge summit of the bordering gneiss and look toward the horizon in any direction it is immediately noticed that all the other ridges and hills rise to the same plane, except those of limestone whose inferior altitude is due to more rapid wear of the softer rock. The plane is not exactly horizontal but shows a slight tilt toward the west, more noticeable on the topographic map than in the natural view. This feature is quite independent of the structure and physical character of the rocks on which it has been impressed and could not be the result of recent erosive work; it marks in fact the base-levelled floor of crystalline rocks that was formed in the late Precambrian period and that by the Paleozoic submergence below the sea was covered with a great thickness of horizontal sediments — Potsdam sandstone and perhaps limestone and shales of the higher formations. In other words the present dissected plane that is so clearly revealed from the summit level is an inheritance that traces back through almost the entire period spanned by the record of the fossiliferous rocks; its preservation is to be explained by the protective mantle of sediments which withstood the effects of erosive agencies down to the Glacial period and of which small remnants are still to be found in the lower ground.

The thickness of the Paleozoic sediments that once covered the district is not known and can only be surmised by piecing together evidences obtained in the outlying country where these strata are better preserved. Cushing [1] has supplied some data on the subject in his work on the Thousand Islands region to the west, in which he concludes that the cover of sediments included not only the Potsdam, but the Trenton, Lorraine-Utica, and the Medina, in all over 2000 feet thick. He sets the maximum for the Paleozoic sedimentation at 3,000 feet, but thinks that limit may largely exceed the real amount. Adopting what seems to be a more conservative estimate of say 2000 feet for the outlying region it is necessary to make a considerable deduction in the figure for the probable thickness of the Paleozoic cover over the Edwards district. The shore on which the sediments were laid down no doubt shallowed rather rapidly, and it was only the higher formations that reached far inland. On the basis of 2,000 feet for the region 25 miles to the west it would appear that a thickness of 1200-1500 feet is quite likely to have been present in this area at the close of the submergence.

[1] Geology of the Thousand Islands Region, N. Y. State Mus. Bull. 145, 1910, pp. 231–4.

Little certainty exists in regard to the physical history of the region in the subsequent part of the Paleozoic period after the marine submergence and the ensuing Mesozoic era. From the proximity of the two regions it would appear likely that the Adirondacks must have shared to some extent in the movements which upraised the Taconic range at the close of the Ordovician. It is also likely that the Appalachian deformation at the end of the Paleozoic was manifested by a very considerable uplift of the Adirondacks. In neither disturbance, however, were the Adirondack formations subjected to compressive forces comparable to those in the earlier period of folding, and the effects were mainly evidenced in the broad elevation of the region as a whole, accompanied by extensive faulting on the east and south sides. In Mesozoic time erosion was probably dominant over the forces of uplift. A base-level condition at the close of the Mesozoic has been postulated by some Adirondack geologists, but that view as well as the theory of renewed uplift in the Tertiary is based upon considerations for which little substantial basis can be found in the region itself.

However uncertain may be the history of the western Adirondacks during the long interval which followed their uplift from the early Paleozoic sea, there is little doubt that erosion had accomplished the removal of most of the sedimentary mantle by the opening of the Pleistocene. When the ice invasion began the surface of the crystallines had been laid bare in places and the limestone valley around Edwards was fully revealed. The ice simply stripped off the remaining layers of Potsdam from the protected ground. It probably performed little erosive work of itself; the surface of the hard crystalline rocks was not substantially changed as a result of the invasion and the present peneplain may be assumed to be practically the floor on which the sediments were laid down.

Limestone valley. Throughout much of their area the limestones have been worn down so as to form a valley, 200 feet or more below the level of the adjacent peneplained ridges. The valley is broad and mature, but the sides rise sharply in a single slope, owing to the great resistance which the gneiss and granite offer to erosion as compared with the limestones. The usually flat valley bottom is broken by a few elevations that mark the occurrence of included bands of silicates or of quartzite; the most notable of these is a ridge of rusty quartzite, 2 miles southwest of Edwards, between the Talcville and Fullerville roads, which attains the elevation of the peneplained gneiss ridges, 180 feet, approximately, above the valley at this point.

The main valley covers only about two-thirds of the limestone belt in the part from Sylvia Lake to Edwards, as it does not follow the latter southwest of the West Branch but swings around to the south parallel with the course of this stream to extend as a gradually narrowing depression to the edge of the Gouverneur quadrangle. The southwestern third of the limestone area has a broken surface much like that of the gneiss country.

The old rock floor of the valley is masked for the most part by glacial deposits. The filling evidently is very thick, as shown by the depth at which the detritus has been encountered at Edwards in the valley adjacent to the zinc deposits. Near the surface the deposits are mostly assorted sands, silt and clay, which from their character as well as their development in terraced beds bear evidence of having been laid down in standing waters. Underlying these are morainal deposits, represented by bowlder clay and unsorted gravels, accumulated during the earlier period when the ice itself stood over the region.

The weak zone of the limestones became a channel for surface drainage just as soon as it began to appear from under the cover of the Potsdam. It was already marked out as a valley, for the Precambrian peneplain showed a depression along its course and the base of the Potsdam here was lower than over the adjoining granite ridges. The exposure of the limestones to a renewal of the erosive activity came sometime before the advent of the Pleistocene ice, probably in the Tertiary which seems to have been a period of extensive erosion for the Adirondack highland. The surface at that time stood considerably higher than now, just how much higher is not known, but probably the difference of elevation is to be measured by hundreds of feet and may have been in excess of a thousand feet. A measure of the former elevation could be deduced if we knew the depth of the rock floor below the existing terraced deposits, but this has not been ascertained definitely beyond the fact that it is considerable. The streams at that time had a more rapid course than now and were engaged in entrenching their channels in the crystalline basement as this appeared from under the sedimentary mantle.

The course of the preglacial drainage from the interior highland was northwest, following the original slope of the sedimentary mantle and the present peneplain. The waters intercepted by the limestone depression were diverted from that course to one at right angles or along the axis of the belt. Whether the flow then was northeast or southwest can hardly be surmised from the topography

of the Edwards sheet alone, but may develop on the completion of the surveys to the north. The present outlet at Hyatt below Talcville on the western side, where the river leaves the valley to cross the gneiss country diagonally to the strike, is certainly quite recent, opened after the retreat of the ice from the valley, but possibly when it still lay over the country to the north and blocked the issue of the waters in that direction.

Terraces. Following the ice retreat came a period of flood waters which stood over the valley to a height of 200 feet or more above the bottom. As a mark of their existence remain the beautiful terraces of well-sorted sands and silts that define the different stages of level which the waters attained at various times. This flood episode was not a local affair, or confined to the western Adirondacks; but was related to the glacial waters known as Lake Iroquois that occupied the Ontario basin and that reached south and east much beyond the confines of the present lake. Embayments of the lake extended into the western Adirondack foothills. The history of this lake has been worked out in detail by H. L. Fairchild.[1] Its waters came from the melting of the ice which still lay across the St. Lawrence valley so as to impond them and raise their level to such a height that they finally escaped over the divide into the Mohawk valley and then into the sea.

The sediment brought down by the Fullerville tributary into the glacial lake built up an extensive delta, whose surface is at about 780 feet, the highest of the terraces. The delta consists of fine quartz sands, much better sorted than the morainal sands. Its surface is now largely a bare sand waste, as the result of removal of the old forest growth, which is gradually extending by the drift of the sand before the winds. The reclamation of the area by replanting to forest with which it was formerly covered should be undertaken. A successful start at this has been made by the International Pulp Company recently on a tract some two miles south of Fullerville. A similar delta marks the entrance of the East Branch into the valley south of Edwards.

In the interval from a little north of Fullerville to Edwards the valley contains many flat stretches lying mostly below the 700-foot contour. These represent the subsiding waters toward the close of Lake Iroquois when the valley had been drained partly and the new channel at Hyatt was being cut through the hard rocks. The lowest part of this terrace is about 660 feet and is well shown at Edwards.

[1] The results of Professor Fairchild's investigations have been given in a number of bulletins and papers issued by the N. Y. State Museum.

Since the escape of the imponded waters by the lowering of the outlet, the Oswegatchie has intrenched itself in the lower terrace to a depth of about 20 feet. It has established a flood plain of considerable extent in the soft sands, notably at Edwards.

Surface drainage. The drainage of the whole district practically is into the Oswegatchie and thence into the St. Lawrence. The East Branch receives most of the tributary streams from the highland area, as it traverses the valley for several miles in a longitudinal direction, while the West Branch crosses it diagonally and has a shorter course. On the southwest end Sylvia Lake occupies a small basin which collects the waters in that part and discharges through a brook that breaks across the gneiss and joins the river below the Hyatt confluence.

The Oswegatchie heads in the swamps and lakes of the interior highland at an elevation of around 1500 feet. Its catchment area above the St. Lawrence discharge at Ogdensburg is nearly 1600 square miles. It is one of the more important streams for power in the northern district of New York and has been the subject of an investigation as to its possibilities for regulation and further power development by the State Conservation Commission.[1] The present power establishments develop a little over 20,000 horse power but the output is not continuous owing to the great seasonal fluctuation of runoff. It is estimated that by the provision of storage reservoirs on the upper reaches to regulate the flow the power capacity could be brought up to 73,000 horse power of which two-thirds would be continuous even in the driest seasons. Such improvement would be a great benefit to the district, for there is a large demand for power among the talc mines and mills, to say nothing of other industries, which can not be supplied under present conditions from local developments. The best power sites in the district are at Edwards and Talcville on the East Branch and Hyatt and Fullerville on the West Branch; at each place the outcrop of gneissic bands within the limestone cause rapids and falls in which most of the vertical descent of the stream is concentrated. Foundations for dams can be placed usually on sound rock.

In the stretch below Hyatt the river flows through a narrow rock channel, with frequent rapid descents, which continues in Hailesboro where it again comes into limestone country and becomes more sluggish. The descent in the 6-mile stretch is a little over 200 feet,

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[1] Power Possibilities on the Oswegatchie river. State of New York Conservation Commission. Albany, 1914.

accomplished mostly by falls which provide some of the best power sites along the river. The greater part of the fall, viz.: 140 feet, is concentrated in the last 2 miles ending at Hailesboro where a number of power developments are situated, including the largest talc mills and a custom electric power plant.

Sylvia lake deserves notice as a drainage feature, and also has claim to attention on account of its scenic beauty which is enhanced by the remarkable clearness and depth of its waters. It occupies a basin of its own, walled by limestone, but practically isolated from the rest of the district. The basin is scarcely larger than the body of water it holds and the sides which consisf of bare rock descend almost vertically to the bottom. Evidently the lake is not of the ordinary class originating through obstruction of drainage lines by glacial debris that is so common in the Adirondacks; likewise the surroundings lend little support to the theory of a structural basin such as would be produced by faulting; and the explanation which seems more nearly conformable with the conditions than any other is that the depression had its beginning in solution cavities produced by the underground circulations and that these were later enlarged by glacial scour. The lake receives very little surface drainage. According to local opinion it is fed by deep springs, a theory which seems very plausible in view of its clear cold waters. The environment of rock cliffs and well wooded slopes lends an effect of primeval wilderness rarely seen so far away from the interior of the Adirondacks.

Underground drainage. Of the water which falls upon the earth in the form of rain and snow, a considerable portion seeps into the soil and rock to join the body of ground water or water table. This water like the surface supply is seldom stagnant, but moves under the influence of gravity from higher to lower levels. The distance at which it is encountered from the surface depends upon several factors, e. g., the seasonal and annual rainfall, contour of the land, character of the rock and the geological structure. In the valleys it comes to the surface in the form of springs to supply the streams, swamps or lakes, while it rises under the hills more or less in conformity with their contour, but with less abrupt changes of level. The circulation of the water through the rocks necessarily is slower than the corresponding surface drainage, for the openings that admit its passage are usually so small as to involve a large factor of frictional resistance. The openings consist in the first place of the small interspaces between the individual mineral grains that compose the rock. The proportion of such open spaces or pores

varies with the different classes of rocks, reaching a maximum in the class of sandstones of about 25 per cent. and being smallest in the massive igneous rocks like granite in which the usual average is but a fraction of 1 per cent. It is evident that the passage of water through such small cavities is slow and takes place largely as the result of capillary attraction.

A second kind of openings is represented by the contact surfaces, bedding planes, joints, fractures and fault fissures that interrupt the continuity of rock masses. These afford a fairly free passage for water and serve as the main channels for underground circulation in the Edwards region.

The limestone belt constitutes the collecting basin for the subsurface waters, just as it does by virtue of its physical contours for the surface drainage. The rainfall upon the surrounding higher ground is brought into the valley by both methods. That the volume of underground flowage is not inconsiderable is shown by the large number of springs at the base of the hills which limit the valley, and particularly by the flow of water in the mines opened in the limestone belt. In the stretch from Fullerville to Edwards occur some 20 talc mines of which 7 or 8 are in present operation. The mines are situated usually on the border of the limestone, following beds of talc that have either limestone or tremolite schist for wall rocks. They are opened by inclined shafts following the footwall, from which levels run off in the direction of strike at intervals usually of 100 feet. The dip ranges from 30° to verticality; the depth is 600-700 feet in the older mines. The flow of underground water varies in individual mines from a few ten thousands to several hundred thousands of gallons a day. All of the mines have to pump more or less steadily. Most of the flow comes from narrow joints and fissures and when localized, as it not frequently is, may be controlled by sealing the openings.

Limestone of all the common rocks is the most soluble by ground waters, and the effects of solution are to be seen in the widening of the joints and fractures, in the course of time producing such openings that waters can circulate with freedom. It is the usual experience in the talc mines that the flow of water is circulated mainly in a few such channels. The quantity does not seem to depend closely upon the size of the mine workings, but rather upon accidents of location with respect to the drainage lines. One mine may tap a large channel, which another nearby will avoid, and the flowage will vary widely in the two instances, although externally their situation seems to be much alike.

Where the sources of the underground waters may lie in such case is difficult to determine, for the channels may be very devious and supplied by numerous subsidiary channels that lead away for long distances. It is noted that very little of the flow comes directly from the surface around the shaft. Several of the talc mines are situated within close proximity to the river, but do not appear to be particularly wet on that account. In one of the mines that lie near the river, it is true, a large influx is encountered, perhaps the largest in the district; but the surrounding conditions are such as to indicate an origin away from the river, probably from the adjacent gneiss country and along the contact with limestone to the north and west. Moreover, the Oswegatchie in its course from Edwards to Talcville flows mostly over silt and glacial beds that are little permeable to downward seepage.

The underground waters of the limestone country it would appear therefore are fed mainly by inflow from the gneiss and granite highland on the borders. Granite and gneiss are close-grained rocks with low porosity and in unbroken mass do not admit the passage of water in any considerable amount; a jointed and fractured condition, however, makes them open to downward seepage and that is the condition of the country formations on the limestone boundaries. Shear zones within which the rock has been crushed into small fragments are not uncommon and in some places are extensive. Along them the water must move freely and be able to reach great depths where they are under powerful head. Along such zones and minor fractures the drainage is conducted into limestone strata where in part it rises directly to the surface in the form of springs, and in part joins an underground movement that follows the direction of the streams.

GENERAL GEOLOGY

In its rock geology the Edwards district shares many of the features that characterize the western Adirondacks. The formations belong to the Precambrian crystallines, a part of the complex of granites, gneisses, schists, quartzite, limestone and dike rocks, which constitutes the western Adirondacks and which on the St. Lawrence county side reaches out beyond the highland into the bordering foothills and plain. In fact the same series of Precambrian rocks can be followed across the St. Lawrence plain to the edge of the river, here and there covered, it is true, by a veneer of later sediments; thus making an isthmus-like connection with the

Laurentian highland of eastern Canada, of which the Adirondack region may be regarded as an outlying province.

It has already been explained that the district once was covered by a sheet of early Paleozoic strata, many hundreds of feet thick. There are still a few isolated remnants of the former covering in small patches of Potsdam sandstone which occur in the valley bottom where their protected positions have saved them from absolute destruction. Edwards marks the inner limit for the Potsdam in this region, and the formation does not appear in force until the more open country below Gouverneur is reached.

The opinion seems still rather common, if the information given out in mining prospectuses and the popular press is any criterion, that the Adirondacks are connected with the other mountain districts of New York and New England, constituting a part of the Appalachian system. This view is altogether erroneous, as a little consideration will show. The uplift which brought the Adirondacks into existence happened far back in Precambrian time; the land area then formed has continued down to the present day, though subjected to great vicissitudes from the work of erosive agencies which toward the close of the Precambric era reduced the surface nearly to base-level so that it was largely submerged by the invading Potsdam sea. After the marine invasion which terminated with the Ordovician came a renewal of the surface by uplift when the whole region emerged and was never again under water. Through all the interval represented by the entire series of fossil-bearing rocks — the historic period of geology — the Adirondacks have escaped the influence of igneous agencies and have undergone little further modification by regional compression; although in that time the Taconic, Green and Appalachian mountain systems were upraised with the accompaniments of folding, faulting and igneous activity on a great scale. No doubt the minor folding shown by the Paleozoic strata on the Adirondack borders and the marginal displacements in the Hudson and Champlain valleys resulted from these disturbances.

The isolation of the region from the influences of metamorphism and igneous invasion during so long a period has been of the greatest consequence from a geological and mining standpoint. In general it means that there has been no counterpart in the Adirondacks of the ore-forming processes to which many of the valuable deposits in the Appalachian belt owe their origin. The region, to be sure, is not lacking in metallic minerals, but the ore bodies are mainly Precambrian and taken together constitute a separate

province, more akin to the Laurentian province on the north than to any in this country.

There exist no equivalents of the gold quartz veins that are found along the Appalachian metamorphic belt, or of the zinc, limonite and maganese ores that accompany the early Paleozoic sediments along the flanks of the system.

The Edwards zinc deposits, as will be shown in a later part of this report, are quite distinct from those of the other productive zinc districts of the country, but find close relatives probably in certain deposits that accompany the Grenville limestones of Ontario and Quebec, across the St. Lawrence river.

Rock Formations

The rocks of the Edwards district may be arranged after the following order, according to their relative ages and modes of origin. The classification conforms in general with the results worked out by Adirondack geologists for the region at large.

Cambrian age — Potsdam sandstone
(Erosion unconformity)
Late Precambrian age — Trap dikes
(Igneous contact)
Early Precambrian age — Granite, pegmatite, gabbro-amphibolite; in separate periods of intrusion.
(Igneous contact)
Early Precambrian age — Grenville sedimentary series, highly altered.

THE GRENVILLE SERIES

The Grenville series, a term first used by Canadian geologists, is the collective designation for those formations which are of sedimentary derivation and which belong to the very early Precambrian. It is a thoroughly metamorphosed assemblage which in the Edwards district includes such rocks as crystalline limestone, graphitic and pyritic quartzite, quartzose schists, garnet gneiss, and various schists and gneisses of very local distribution. There are also exposures of dark amphibolitic gneiss whose derivation is uncertain, though relationship with the Grenville is suggested by the features of field occurrence. It is to be recognized, however, that rocks of this same type are produced by metamorphism of

igneous originals of the gabbro family; and the question of origin in this instance will be left open.

The crystalline limestones, schists, quartzite and gneisses constitute just such an assemblage as would result from the recrystallization under pressure and heat of a varied assortment of sediments like that to be found in almost any stratified series of Paleozoic or more recent age. The crystalline limestones represent thus the metamorphosed equivalents of granular calcareous rocks which were probably formed under water by accumulation of fossils or by chemical precipitation. The existence of life at the time of their deposition is suggested by the occurrence of graphite, as well as by the carbon which enters into their composition. The quartzites are old sandstones and silts; while the schists and gneisses may well represent the fine products of sedimentation, with their large content of clayey matter.

The sequence of the several Grenville formations from bottom to top is unknown. In their present folded, faulted and highly eroded condition it is extremely difficult to obtain definite information as to their present structural relations, and it seems almost a hopeless task to ascertain the original succession or even to discover which formation lies at the bottom and which at the top of the series. The structure of the Edwards limestone area, as will be shown later, appears to be synclinal with the limestones overlying the garnet gneiss.

Limestone. In the outline of the distribution of the limestone included in the preceding discussion of physical features, the outcrop was described as a belt elongated in a northeast-southwest direction parallel with the strike of the beds. This holds true in a general way, but is subject to important modifications so far as it implies any marked degree of regularity in the outlines of the area. It will be observed from the sketch map on which the contours of the outcrop are shown, that the northern margin follows a fairly straight course from the point of curvature where it bends around to the west of Sylvia lake to the eastern limits of the Gouverneur sheet, beyond which the belt has not been traced for lack of serviceable maps. In this part the limestone is bordered by amphibolite and granite. A mass of amphibolite south of Emeryville bulges out into the limestone forming a slight convexity on its margin. Northeast of this red granite constitutes the wall, the contact crossing the Oswegatchie one-half mile below Talcville and continuing thence northeast to beyond the Edwards zinc mines. Near Talcville the limestone is split by a band of dark hornblende-biotite gneiss which

follows the northern contact so as to leave a narow limestone band scarcely one-fourth mile wide between it and the granite. This gneiss strip is continuous all the way to the zinc mines. It is injected by red granite and contains small bodies of unmixed granite and pegmatite. The gneiss has an extremely varied mineral composition, ranging from a very quartzose rock with small amounts of feldspar to a dark biotite-amphibole schist, and is probably an interbedded layer of the Grenville.

The south side of the belt shows notable departure from the normal northeast-southwest course of the opposite margin. Near Fowler a great boss-like mass of amphibolite crowds in on the limestone from the south, just as the Emeryville body does on the north side, so that the belt just east of Fowler pinches down to a neck barely half of a mile wide, the narrowest part in the whole district. The eastern margin of this amphibolite mass is deeply notched and the limestone fingers out into it. One of these limestone offshoots crosses the West Branch just below the Fullerville bridge and extends south for quite a distance over the ridge finally tapering down to a point a mile or so south of the river.

It is this band of soft rock that causes the lower rapids, but the falls above are over ledges of hard amphibolite. The river south of Fullerville, as far as the southern limits of the Gouverneur sheet and beyond, flows over this rock which presents a wedge-shaped front to the limestone.

A singular extension of the limestone occurs between this amphibolite area and the rugged gneiss country which lies to the east. A narrow belt, half a mile or less wide, intervenes and continues south beyond the margin of the Gouverneur sheet, its surface being covered over much of the distance by the terraced sands. Here and there the winds have bared the limestone, so as to leave no doubt of the continuity of the band with the main area. This band may continue south, so as to connect with the Harrisville area, but that point has not been actually determined by the writer. It is remarkable that the West Branch should follow for a long distance the hard amphibolite when the limestone lies in close proximity.

Near the eastern margin of the belt on the south side the limestone is in contact with gray garnet gneiss and here the relations become much involved. The limestone winds around long wedgelike protusions of the gneiss which have the appearance and structure of anticlinal ridges that pitch northeast. This is the clearest case of interfolding of the limestones with the silicate rocks that

has been found and affords a basis for determining the larger structure of the main belt itself.

Within the limestone occur many exposures of schists, gneisses, and quartzite which have not been indicated in the sketch map, most of them being too small to note separately. The largest of the foreign bodies is the mass of pyritic schist and quartzite which forms the prominent hills southeast of Talcville. Another body of this quartzite occurs near Mud pond in the Sylvia lake region. Such quartzite is a common feature of the Adirondack Grenville and can be safely regarded as one of the regular sedimentary members.

In distinction from the rusty, more or less graphitic quartzite, a white vitreous quartz occurs rather abundantly as interleaving bands and irregular masses, which are apt to project prominently as bare ledges out of the limestone country. There is much of this kind of quartz around Sylvia lake and also in the vicinity of the Edwards zinc deposits. Although the quartz not infrequently occurs in alternating bands with the limestone, so as to appear interbedded with it, there is good reason to believe that much of it is of secondary character, contributed in the process of igneous injection and mineralization. Its occurrence as an occasional accompaniment of the gangue minerals of the zinc ore, and more abundantly in the walls adjacent to the bodies, as an ingredient of the talc, and in large bands and irregular masses within both the limestone and the silicate formations may be noted.

Chemically the limestone belongs to the dolomitic class, in which the proportions of lime and magnesia approximately correspond to their molecular ratios. A little calcite may be found intercrystallized with the dolomite grains, but it is exceptional for the calcite to attain any large importance as an ingredient. The several Grenville belts of the western Adirondack region show marked differences among themselves in regard to their relative content of magnesia and lime and to some extent the same variation holds true for a single area. A few miles south of the Edwards district is the parallel Bonaparte Lake-Harrisville belt, the two possibly connected by a narrow tongue of limestone extending along the West Branch of the Oswegatchie, that is predominantly calcitic with minor amounts of dolomite; while the area about Gouverneur to the west of the Edwards district is also a calcite limestone, with here and there exposures of true dolomite. Whether the variation is a primary feature in the sense that it traces back to the period

of deposition of the limestone can hardly be determined at present, with so little known as to the sedimentary succession during the Grenville time. The evidences are too meager on which to base any conclusion in the matter. It is pertinent, however, to note that there has occurred a local transference and readjustment of the lime and magnesia components in the period subsequent to the uplift of the limestones, instanced by the development of the tremolite schists along the borders of the belt, which whether originating from impure siliceous layers of dolomite or from silication of calcite limestones could only have been produced through a change in the molecular ratio of the two ingredients.

In physical appearance the rock is medium to coarse grained, normally white, but mottled or streaked more or less by silicate inclusions. The part played by the silicates is exceedingly variable. They are never absent, though in some exposures sink to small proportions, and the limestone then has the character of a white marble, for which it has been quarried to a limited extent. The best development of this phase is to be seen on the ridge west of Fowler post-office, which a few years ago was the site of small quarry operations by A. B. Scott of that place. Analysis of a sample of the stone furnished by Mr. Scott showed 8 per cent insoluble matter, mainly in the form of small scales of phlogopite and round quartz grains, and 18 per cent magnesia, indicating a fairly pure dolomite.

The silicate impurities generally are much in evidence. Most commonly they consist of tremolite and pyroxene, and their alteration products talc and serpentine. The tremolite occurs in bladed and fibrous aggregates which are interleaved with the carbonates or else form considerable bands along the borders where they may alternate with the limestone across the bedding. The field relations are such as to leave no doubt of the derivation of the tremolite schist from the limestone. The pyroxene, a white, monoclinic variety identified as diopside, occurs in disseminations through the mass of the limestone, but rarely or never is so abundant as to constitute a rock of itself. The two minerals do not seem to be associated to any extent. The tremolite is developed mainly in the border zone; diopside on the other hand is the common silicate within the interior where it is mainly found in isolated grains and prismatic individuals embedded in the carbonates.

Both tremolite and pyroxene are the result of a metamorphic change which occurred before the limestone had been uncovered, that is in the early Precambrian, during the period of igneous

intrusion and general deformation from regional forces. So much is evident from the field relations and from the paragenesis of the minerals. But the particulars of the metamorphic process and the related time of its occurrence with respect to the intrusions are less certain. These subjects will be taken up again in a separate place where they can be more appropriately discussed.

Secondary alteration of the tremolite locally has given origin to deposits of talc, mainly of the pseudomorphic variety, which preserves the fibrous or bladed habit of the original. The change from tremolite to talc is a gradual one, proceeding from the exterior of the crystals toward the interior, and can be observed in thin sections in its various stages, as has been described by C. H. Smyth, Jr.[1]. Without entering into details of the evidences at this time, it may be said that the alteration does not appear to be the result of mere surface weathering, but has taken place within restricted zones and at depths which lead one to infer the activity of heated vapors and waters. Along with the pseudomorphic fibrous talc occur smaller bodies of the foliated variety, deposited directly from solution in fissures and other openings within the beds which probably served as the channels for the underground circulations active in the conversion of the tremolite. In some deposits scaly or foliated talc occurs interleaved with the fibrous to a small extent, but in general the foliated is found in separate bodies, whenever it exists in large amount.

Alteration of the diopside leads to the formation of serpentine rather than talc, and very little of the latter can be traced to pyroxene as the parent mineral. Certain lenticles or knots which occur in the limestones are formed of diopside, more or less changed to talc, but the resultant product lacks the fibrous character of the tremolite derivative, having a massive appearance in the hand specimen. These knots are sometimes surrounded by rims of serpentine, which apparently has formed at the expense of the talc. The talc is of darker color than the tremolite derivative which is usually pure white and free from iron. The nodules are distinguished by the local miners as black talc.

Quartzite. Quartzite and quartzose schist, in massive to thinly laminated layers, charged with pyrite and graphitic carbon, is one of the characteristic members of the Adirondack Grenville, seldom failing where any considerable development of these rocks occurs. In the field it is closely associated with the limestone. Its occur-

[1] School of Mines Quarterly, Vol. XVII, p. 333, 1896.

rence is a good indication of limestone country, but it has a rather patchy distribution and occupies a much smaller area than the calcareous rocks. The individual exposures are seldom arranged in belts, but suggest the broken disrupted parts of once continuous beds which have undergone great disturbance from regional forces and igneous invasion.

The structure of the quartzite is rarely determinable with any degree of certainty. Such evidence as has been forthcoming, however, indicates a conformable arrangement with the limestones, rather than otherwise, and it may be held, for the present at least, to represent the siliceous element in a conformable sedimentary series — the metamorphosed equivalent of quartz silts and sandstone. By the entrance of aluminous impurities it passes over into feldspathic schist in which biotite assumes importance. The tendency of the quartzite to yield to pressure by fracture and displacement shows itself in strong contrast with the plastic flowage of the associated limestone and accounts in some measure for its more patchy distribution.

In the Edwards district the information is not sufficient to justify any conclusion as to the horizon of the quartzite in the Grenville. Only two extensive exposures occur; in both the beds exhibit a highly inclined attitude, in dip and strike following approximately the arrangement of the limestone, that can best be explained on the assumption of compressed folding, with subsequent dissection by erosion.

A ridge of the quartzite and quartzose schists rises out of the limestone valley 2 miles southwest of Edwards on the Fullerville road, being a conspicuous exception to the general level character of the neighboring area. Its surface is thinly soiled or bare owing to the formation of sulphurous acids that are destructive to vegetation by the gradual oxidation of the pyrite that is disseminated through the rock in considerable amount. The bare ledges have a burnt reddish appearance like the capping of a mineral vein. The quartzite with intercalated layers of limestone covers a surface of over one-half a square mile, but the beds are cut off abruptly on their line of strike by the limestone which surrounds the area on all sides.

The other exposure is in the southwestern part, along the northern margin of the limestone belt, between Fowler and Mud pond. A band of quartzite and graphitic micaceous quartz schist extends along the north side of the ridge that begins just west of Fowler

post office; it has limestone on both sides, so far as can be seen in conformable arrangement, with a dip to the north. There are intercalations of limey layers which become more prevalent on the south side where the quartzite gives away rather abruptly to a white fairly pure dolomitic marble. The contact on the north side of the band is usually concealed. On the west and near Mud Pond shallow pits have been sunk in exploring for pyrite which occurs in considerable amount, but rather streaky, on the whole too lean an ore to be of commercial value. This band is perhaps a mile long and up to 400 ft. across.

Under the microscope the most conspicuous features of the material relate to the pyrite and graphite which are present in greater proportions than appear from microscopic examination, since they occur to a considerable extent in minute disseminated particles scarcely noticeable in the hand specimen. The graphite is in the form of scales and dust, gathered largely about the pyrite. This association of sulphide and carbon is too constant to be merely accidental, and is to be explained no doubt on the basis of some genetic principle. Many of the larger pyrite grains show imperfect crystal boundaries against the quartz as evidence of growth by replacement. Small veins and enriched bands occur in certain limited zones which also suggest a secondary deposition of the pyrite. The smaller disseminated grains, however, may well represent an original constituent of the sediment, and the source from which the later generation of the mineral has been derived. In some parts of the exposures more or less pyrrhotite accompanies the pyrite, and in the Mud Pond locality it occasionally predominates over the other sulphide. A varying proportion of feldspar enters into the composition of the quartzite; normally the amount is small, but in some beds it becomes important and then enter also iron-magnesian silicates of the mica or amphibole groups. This marks a passage to a schist or gneiss which still retains its content of graphite and pyrite.

The pyritous quartzites of the Edwards district no doubt are related to the other occurrences of the mineral in St. Lawrence county which have been the object of mining operations for sulphur ore, but in so far as they have been prospected are too lean to be commercially important. Active mining for pyrite is in progress near Hermon, north of Edwards, where the matrix of the sulphides is a quartzose graphitic gneiss of sedimentary affinities and the deposits occur in the form of bands and lenses of large

size. There are deposits at High Falls, near Canton, that have been worked; and just north of Gouverneur. These richer deposits, however, differ from the lean disseminated type here described in important particulars, showing unmistakeable evidence of concentration by metasomatic processes to an extent which is only faintly suggested by the slightly enriched portions of the present beds. Their study by C. H. Smyth, Jr.,[1] has brought to light evidence that much of the pyrite was formed after the regional metamorphism of the schists and their intrusion by igneous rocks, probably by the conversion of iron silicates and oxides into sulphides through H_2S vapors derived from the cooling magmas. A proportion of the sulphides of course may have existed before the mineralization, but the latter is responsible for its segregation into deposits of workable character as illustrated by the occurrence named. It is noticeable that the pyrite deposits in the quartzite and gneiss carry very little zinc. Vugs are encountered now and then in the Stella mine at Hermon that are lined with crystallized quartz, pyrite and blende, and occasionally a little blende may be seen included in the ordinary ore, but the amount altogether is exceedingly small.

Grenville gneisses. On the borders of the Edwards district in contact with the limestone occur various feldspathic foliated rocks which in their field relations or other particulars show marks of sedimentary origin. So far as the evidence goes it indicates that they belong to a single succession conformable with the limestone and quartzite; but there is little about their structural development that can be relied upon to establish the original order of arrangement of the sediments. Their equavalents are widely represented over the Adirondack region, and the field studies elsewhere may be drawn upon for light on the problems connected with their recognition and classification, much more difficult than those presented by the other members of the Grenville.

The existence of feldspathic representatives in the Grenville may be postulated with some degree of certainty, even without the evidence to be had in the field. Aluminous sediments are a necessary complement to the large accumulation of calcareous and siliceous materials which have already been described. They comprise the argillaceous element in the process of rock disintegration and decay, characterized by a considerable content of alumina combined

[1] On the Genesis of the Pyrite Deposits of St. Lawrence county, N. Y. State Mus. Bull. 158. 1912.

with silica, but also holding more or less iron, alkalis and alkaline earths. With the agency of water in sorting the rock waste, as well as in transportation and deposition, which is inferred from the well-sorted stratified condition of the other sediments, the clayey materials naturally would come to deposit. Metamorphism of clays and clayey silts leads to the formation of feldspathic schists, gneisses, etc., of character varying with the composition and degree of recrystallization in each particular instance.

Of course the make up of the pre-existing rocks from which the Grenville sediments were derived is a factor that would be of interest to consider in this connection, but nothing can be definitely stated in the matter for there is nowhere exposed any surface which so far has been recognized as the basement on which the strata were deposited. They rest in places upon a more massive granitic gneiss, but the relations are always found to be that of intrusive contact and not unconformity.

The aluminous sediments by metamorphism have undergone more far-reaching changes than have occurred with the rocks of simpler composition, and are consequently so much the more removed from the originals in their mineral composition and internal structures. Their discrimination from gneisses of igneous origin is often extremely difficult since in the process of metamorphism by pressure and heat the mineral combinations are much the same as those resulting from the cooling of chemically similar igneous magmas.

The sedimentary gneisses in the Edwards district have undergone further transformation by admixture with magmatic materials, particularly granite. In nearly every exposure they may be seen to be cut by dikes or veined and banded by a network of intersecting stringers of granite and pegmatite, which stand out in strong contrast by their fresher appearance and usually bright pink or red color. The proportion of this injected matter is extremely variable, ranging on the one side from an occasional stringer insignificant in mass to a condition of thorough injection in which the igneous element may overbalance the sedimentary base. Along with the injection which in extreme cases results in a mosaic pattern of the two materials has occurred a greater or less diffusion of the magmatic ingredients all through the body of the sedimentary gneiss, as if the latter had been drenched, so to speak, in the liquid magma. This amounts to a real addition of the igneous material and results in the formation of intermediate types which cover an indefinite field outside the lines drawn in the usual systems of rock classification.

The details of the process of injection and drenching as revealed in the field and laboratory study of the gneisses contain much of general interest, but they belong rather to the subject matter of the areal report which is under preparation and where no doubt they will receive consideration. It is of importance for the present purposes to note that they indicate the seat of invasion to have been at great depths, under conditions of pressure and heat that induced resoftening and plastic yielding of the sediments. The latter had already been thoroughly recrystallized and probably more or less folded by regional compression. The granite and pegmatite which caused the injection are themselves very little deformed by compression and have a fresh bright look compared with the other rocks that indicates their later consolidation.

The injected types of the gneisses prevail over much of the area occupied by the Grenville silicate formations on the borders of the Edwards district. It is rather rare to find any considerable body of the gneiss which has not received some contribution in this way. The presence of magmatic material is not always evident in a general examination of field exposures, for it may be so diffused as to cause no appreciable change in the texture or color of the gneiss; as a rule, however, the injected rock shows the effects rather plainly, for the magmatic ingredients have a tendency to a coarser crystallization than the matrix and often lend a porphyritic appearance to the aggregate. At the same time the injected materials show a contrast in color, usually being lighter than the matrix.

The admixture of granite in varying proportions and methods of injection adds much to the complexity of the problems connected with the derivation of the Grenville gneisses which at best offer great difficulties in that particular. It must be acknowledged that the classification of the gneisses on principles based on the character of the original sediments is at present scarcely practicable, for the accidents connected with the metamorphic changes which they have undergone are too little understood and out of reach of calculation. In addition to those changes which may be referred to regional compression and to which all the sediments have been subjected on a more or less uniform scale, the possible influence of local igneous intrusions antedating the red granite and the introduction of magmatic materials along with them has to be considered. Such earlier intrusions that may have been influential in this way are exemplified by the great sill of gabbro-amphibolite on the southern margin of the district and by the appearance here

and there of granitic rocks which are thoroughly gneissoid in appearance and thus probably of an earlier generation than the common red variety.

One of the common gneisses in the vicinity of the limestone with which it seems to be a close associate is a gray garnet gneiss. This has an extensive development along the borders of the belt south of Edwards in the rugged area between the South Edwards road and Clear lake. It also appears on the opposite side, around Cedar lake and southwest of there, but with a body of granite intervening between it and the limestone. Such garnet gneiss has been noted in various parts of the Adirondacks and altogether covers a wide area. It is a medium to fine-grained mixture of quartz and alkali feldspar, with variable biotite and scattered brownish red garnets, in some places carrying scapolite and sillimanite, and occasionally heavily charged with magnetite or pyrite. It is banded by coarse granitic material. The texture is gneissic and the structure often shows extreme contortion. Small bands of limestone are interbedded or interfolded with it. The interesting contact features of this gneiss with the main limestone area, as exhibited in the sections south of Edwards, are described on page 44.

Reference has been made to the narrow band of dark colored gneiss which lies along the border of the limestone belt, but still within it, from Talcville to the Edwards zinc mines where it constitutes the covering rock to the limestone that encloses the ores. Its close proximity to the Edwards zinc bodies which it overlies and of the Talcville talc beds below which it extends renders a description of its character and field features of special interest. The band is seamed with red granite which also appears in small bosses and lenses with irruptive contacts, and in places the granitic material predominates over the darker rock. Along with the finer granite and independent of it, occurs a bright red pegmatitic granite carrying black tourmaline. Both granite and pegmatite have soaked the gneiss which often takes on a distinct pinkish tinge through the development of secondary feldspar. The normal dark color of the gneiss is deceptive as to its composition, for the material is not so basic as would appear at first sight, since there is a good deal of free quartz and the feldspar is mainly of the alkali variety. Biotite is the chief iron-magnesian mineral, though its place may be taken in part by a green hornblende. Magnetite shows up prominently in thin sections. The combination of high magnesia and iron, low lime and relatively high alkalis and silica, indicated by the mineral

composition, is hardly normal for an igneous rock, and it is regarded by the writer as an interbedded sedimentary layer. A variable but quite persistent content of graphite in the form of small flakes disseminated through the groundmass further strengthens this view. In its field relations the gneiss appears to conform with the structure of the enclosing rock, so far as this can be determined. At least there is no definite evidence that it anywhere breaks across the bedding of the limestones; unless possibly this should be the condition in the limestone ridge which contains the Edwards zinc deposits, for here the gneiss winds around so as to head off the limestone on both the northeast and southwest ends. But the structure of the limestones in this locality is not sufficiently clear to establish the actual conditions.

GABBRO-AMPHIBOLITE

This term is applied to certain bodies of basic hornblende gneiss which outcrop within the district and which seem to bear little relation to the identifiable members of the Grenville. It is recognized that the igneous origin implied by the term is somewhat uncertain, since there are no direct evidences of such derivation in the way of contact effects upon the bordering formations or in the internal character of the amphibolite itself. The general features, however, are more akin to those usually associated with gneisses of igneous derivation.

From the biotite hornblende gneiss described under the Grenville formations the rock shows contrast in its prevailingly coarser crystallization and greater uniformity of composition. The color is dark, almost black, due to the abundance of hornblende with associated biotite, which with feldspar constitute practically the mass, although quartzose phases do occur. Garnet is a variable ingredient, abundant in places and again sparing in quantity or absent. The texture is foliated and markedly so, as a rule, but occasionally approaches a massive condition, without however much suggestion of the peculiar mottled effects that characterize unmodified gabbro. Field examination in the course of several traverses of the mass revealed no clear case of a gabbro phase that might represent a core that had escaped the general metamorphism, and there seems little hope of finding such evidence. It is not unlikely that the contact relations with limestone would yield decisive information, if exposures of the two rocks in conjunction were at all common, which unfortunately is not the case.

As a further consideration which bears upon the problem of the derivation of the amphibolite, attention may be called to the existence of metamorphosed gabbro in the vicinity of Pyrites, between Edwards and Canton, which have been described by Smyth [1] and more recently examined and mapped by Martin.[2] The bodies of pyrite are found in rusty quartz gneiss which is bordered by a black basic gneiss which contains more or less pyroxene in addition to hornblende and also possesses true gabbroic characters in certain parts of the area. The field relations also indicate an intrusive origin for the amphibolite. From the information that is given it would appear that the rock is much like some of the amphibolite exposed around Fullerville although the similarity does not extend far enough to make it of decisive value.

One of the main exposures of the basic gneiss is on the southern limits of the Edwards district. It is encountered along the course of the West Branch from Fullerville south to the limits of the Gouverneur sheet and beyond into the area of the Lake Bonaparte quadrangle. The rapids and falls at Fullerville are formed by ledges, diagonal to the stream course, of the hard rock which have been made prominent by the more rapid wear of the limestone below, over which the stream has a winding sluggish course from Fullerville to Hyatt where it leaves the limestone and passes out of the district. As exposed in this vicinity the amphibolite may be defined as a tongue, projecting northward into the main limestone area and narrowing rapidly in that direction, bordered on either side by narrow bands of limestone that are offshoots from the larger body. With its southerly continuation it appears to have the structure of a long north-south sill that has been intruded into the Grenville. A contact of the gneiss and limestone is found across the highway from the Ontario Talc Company's mill at Fullerville; it shows an irregular boundary with the two rocks tightly frozen, such as would be expected in the case of an intrusive, but there appear no visible evidences of igneous action upon the limestone.

Amphibolite of very similar nature limits the limestone belt on both sides where the belt narrows east of Fowler. Here the limestone is reduced to a mere neck, less than one-half of a mile across, between exposures of amphibolite that apparently are part of quite extensive bodies. The constriction may be interpreted as the result of squeezing of the soft pliant limestone between two resistant

[1] Eighth An. Rep. Director N. Y. State Mus. Bull. 158, 1912, p. 160 et seq.
[2] N. Y. State Mus. Bull. 185, 1916, p. 61 et seq.

blocks of the hard gneiss, but the alternative of igneous intrusion and digestion can not be excluded as a possible explanation. It is noticeable that somewhat the same relation holds where granite borders the limestone.

In age the gabbro-amphibolite is certainly early Precambrian, for its highly schistose character and the extensive mineral changes that have taken place point to a time of intrusion preceding the period of profound regional metamorphism. It is also older than the red granite which has invaded and injected it in the same manner as described with reference to the Grenville gneisses.

GRANITE

The most important single element among the Precambrian formations bordering the limestone belt is granite. There likely is more than one variety and period of intrusion represented, but the prevalent type is the red granite so frequently mentioned as the medium of injection of the gneissic rocks.

This granite was the last of the intrusions which invaded the gneisses and limestones under deep-seated conditions. Only a few scattering trap dikes of late Precambrian age mark the continuance of igneous activity after the granite and its accompanying pegmatites had reached their present place. It is encountered in larger or smaller bodies all through the region, and is the most conspicuous, also in many ways the most interesting, of all the formations. As a mineralizing agency it especially deserves attention.

Mineralogically the granite is not remarkable, having a very simple composition. It is mainly a mixture of feldspar and quartz, with a moderate to small amount of dark components in the form of biotite and hornblende. The feldspar is chiefly of the alkali kinds—microcline, albite and microperthite—with a predominance of the potash element over the soda as in normal granites. The proportion of free quartz indicates a fairly acid type of magma, which is also to be inferred from the abundance of pegmatite and quartz veins that accompany it. The texture usually is coarse, often porphyritic, but in places becomes finer and even granular. Its bright fresh color and massive appearance are distinctive features not shared by the other intrusives.

The manner of occurrence of the granite has already been covered particularly in the description of the injected gneisses. But in addition to the dikes and network of interlacing stringers and threads it occurs in lenses, small stocks and bosses, and

occasionally in long tongues that reach out parallel with the general structure of the country rocks. It is quite likely that all of these various bodies are but the outlying parts of an extensive granite batholith, as was remarked by the writer [1] in a brief report on the district made in 1911.

Their uniformity of mineral character preserved throughout the innumerable individual occurrences can hardly be explained except on the basis of a common reservoir from which the material issued to be fed to the smaller stocks and then to the ramifying dikes and stringers.

It is interesting to note that a great area of granite of very similar character occurs in the southeastern part of St Lawrence county, some 15 miles distant from the Edwards district. This has been described at some length, but its full extent is not yet known though it certainly covers many square miles. Until the intervening region has been explored the relation of this body to the Edwards exposures can not be safely predicted, but the similarity of habit is at least noteworthy. Chemical analyses of the rock are given in N. Y. State Museum Bulletin No. 181.

An extensive development of the granite in the immediate vicinity of the limestone belt occurs on the southern border, near Pleasant Valley school. A broad tongue of the granite projects northward into the limestone country. Its surface has not been fully explored and the northern edge composed of a series of steep ridges that rise out of the limestone valley in a semicircular arc may prove to be a stock, or more likely the termination of a sill which extends well to the south. The northern part where traversed is exceedingly rough, almost impenetrable, by reason of the gigantic boulders which have been loosened from place and the many ledges which present their perpendicular joint surfaces as a bar to progress. The granite has a coarse, porphyritic, massive appearance, with a tendency to a linear arrangement of the constituents which seem more like flow structure than pressure foliation. Inclusions of Grenville are occasionally to be seen.

Unbroken exposures of the granite occur on the north side in the vicinity of Talcville and northeast of there along the limestone contact. Altogether the granite probably comprises 50 per cent, if not more, of the rock material on the immediate borders of the district, taking into account the small intrusives which are not infrequently encountered.

[1] N. Y. State Mus. Bull. 161, 1912, p. 103.

Besides the coarse massive granite as described, a fine-grained gneissic type occurs in small amount. One of the more important exposures is along the ridge behind the Edwards school-house, at the north end of the village. The ridge is mainly Grenville gneiss and limestone, but on the north side these are intruded by a much jointed pinkish rock which encloses blocks and fragments of both in its mass. The gneiss has a thoroughly mashed look in the hand specimen, the minerals all being so finely divided as to be scarcely separable to the eye, and the appearance of crushing is confirmed by the microscope which reveals a mixture of quartz and feldspar in broken angular particles, with an occasional fragment of a larger crystal. There is no mica or hornblende, but the former existence of one of these minerals is inferred from aggregates of chlorite and magnetite. The composition is very acid, from 75 to 80 per cent SiO_2, considerably above that of the massive granite.

The difference in composition and physical character point to a separate and earlier period of intrusion for this granite. Such conclusion conforms with the general results of geological work in the Western Adirondacks, and more particularly with the recent studies of Cushing around Gouverneur where the presence of an older and younger granite has been established. The older granite is termed "Laurentian" by Cushing, although it is recognized as later than the Grenville. The more massive porphyritic granite may be called Algoman, after the classification of Canadian geologists.

The older gneissoid granite has exerted little influence relatively in the modification of the country rocks. The younger representative is mainly responsible for the phenomena of injection and igneous assimilation which have been noted with reference to the Grenville gneisses.

Pegmatite and magmatic quartz. The last phase of the granite invasion was marked by the emission of mineralized solutions and vapors which permeated all of the formations so far described. These solutions represented the residue or juice of the igneous magma after the main body had consolidated, still held liquid by the abundance of solvent ingredients — chlorine, fluorine, boron, water, etc. They were consequently very tenuous and mobile, capable of penetrating into the pores and cracks where they deposited their burden of mineral matter. The direct products of their activity are to be found in the pegmatites and vein quartz, which occur not only in the bordering gneissic rocks, but within the granite itself.

Both materials are abundant, though pegmatite is much more

common. It occurs in dikes, stringers and irregular patches, but never in large independent bodies like the common granite. The dikes are seldom more than two or three feet wide; exceptionally they reach 15 feet. In addition to white quartz, pink microcline, and some biotite or hornblende, they carry rather abundant tourmaline of coal black color in prismatic crystals. Their texture is coarse, varying with the size of the body, the extreme being reached with feldspar individuals over a foot in length. Their mineralogy is simple, like that of the granite from which they are derived.

Vein quartz accompanies the pegmatite in the field in such relations as indicate its common source and contemporaneous development. It represents only the extreme siliceous phase of the segregation process which produced the pegmatite. Schlieren or masses of pegmatite that have crystallized in place are found within the granite, the two rocks then grading into each other by imperceptible stages. Some are very quartzose and mark a transition to the lenses and stringers of vitreous quartz that are also present.

It is believed that most of the quartz veins and bodies of vitreous quartz found in the gneisses and limestone which show evidences of more or less deformation by regional forces are referable to the granite magma. Quartz is more abundant in the limestones than pegmatite. It is much in evidence in the vicinity of the Edwards zinc deposits, where it accompanies the ores as one of the less abundant gangue minerals and as bands or veins in the country limestone. In the Sylvia lake region the limestones are banded with white quartz so as to simulate more or less the appearance of a bedded arrangement.

Contact rocks. Direct contact action between the granite and limestone is only rarely to be seen under conditions which leave no doubt of the nature of the occurrence. In a few places, notably at Talcville where the granite and limestone are exposed in close proximity, exomorphic change is clearly shown in the development of secondary silicates within the limestone. The minerals thus found include diopside in large prismatic individuals of green color, while feldspar, phlogopite in amber or greenish sheets of fairly large size, and small well-crystallized titanites. Wernerite and apatite are also recorded as occurring in this vicinity.

It is to be noted that the contact of the limestone with the granite or with the other silicate rocks for that matter, is seldom exposed. In most places the edge of the granite is quite remote from the nearest limestone outcrop, a fact that no doubt accounts in large

measure for the paucity of similar evidences of contact metamorphism.

The widespread development of tremolite and diopside in the limestone, as noted in the description of that rock, can not be definitely referred to contact activity but it is very likely connected with it. There is little about the occurrence of either mineral which points more or less directly to the mineralizing influence of the granite. Such evidence as has been found in the field is rather confusing and does not suffice to determine the conditions under which the change took place, or the relative time further than it preceded the completion of the regional deformation as shown by the squeezing and folding of the tremolite schist. C. H. Smyth, Jr., [1] has remarked the tendency of the tremolite schist and the derived talc deposits to follow the structural lines of the limestone. In shape the talc deposits may be likened to attenuated bands which show many irregularities in the way of rolls and pinches, but whose length and breadth exceed many times their thickness and generally conform with the directions of dip and strike of the limestone wall rock. Their actual stratigraphic position, however, is hardly determinable in view of the plastic flowage which the limestone itself has undergone; but it is noticeable the developed mines and also the prospects are more frequently found near the contact than away from it, and that few or none occur in the middle of the belt. The Talcville mines form a more or less connected group in linear succession, extending altogether over a distance of a mile and a half. They have the granite or injected gneiss on the north side at distance of from 100 to 1,500 feet, the interval being made up of serpentinous limestone, with small bands of tremolite schist. The mines in the vicinity of Sylvia lake also have a linear arrangement but occur on the south side of the belt, a few hundred feet to one-half mile distant from the nearest granite bodies on the surface.

On the whole it would appear that the tremolite schist is developed more abundantly near the borders of the limestone and the most persistent belt is found on the north side in vicinity of the rather extensive granite body which intervenes between the limestone and the garnet gneiss from Talcville to near Cedar lake north of Edwards. The Sylvia lake talc deposits occur as sporadic bodies within the limestone, at varying intervals from the contact with the granite or amphibolite, and often contain considerable proportions of crystalline or scaly talc rarely found in the northerly section.

[1] School of Mines Quarterly, Vol. XVII, 1896, p. 333.

TRAP

The last phase of igneous activity was manifested by the extrusion of a dark basaltic rock that found its way to the surface probably to cool as a lava flow. No remnants of the surface lavas remain, and could hardly be expected to have survived the tremendous erosion which ensued down to the opening of Cambrian time. The channels through which the lava was erupted remain, however, with their filling of igneous rock from the last outpouring.

In the limits of the Edwards district two occurrences of the trap have been found, and probably several more exist. One of them is on the ridge, back of the Edwards school-house, where a two-foot dike cuts the granite gneiss in an east-west direction. The second occurrence is in No. 2½ mine of the International Pulp Company at Talcville where the rock was seen in the waste recently taken from the underground workings. Both examples show extensive alteration to an aggregate of chlorite and serpentine, but contain enough of the original minerals to identify them with the common traps of the Adirondacks which are made up mostly of pyroxene, feldspar and magnetite. The trap from Talcville contains more or less garnet which is probably the result of contact action with the limestone.

POTSDAM SANDSTONE

Of the original mantle of Potsdam sandstone which once covered the whole series of crystalline rocks, only a few isolated patches representing the lower beds, remain, and these are restricted to the limestone valley. It is rather noteworthy that any remnants should have survived the wear of the land since its uplift and exposure to erosion during so long a period as has elapsed from the Paleozoic submergence. The few outcrops that still exist lie in protected positions in the lowest part of the valley. There is reason to believe also that faulting has been a factor in their preservation. The beds in two of the occurrences are tilted and broken to an extent that indicates that they have been involved in movements of some magnitude.

The sandstone is a granular grayish to rusty rock, showing conglomerate layers in places. It has undergone considerable local alteration. The finer-grained phases in such condition can hardly be distinguished from the Grenville quartzite. The bottom layers next to the limestone may contain a considerable proportion of hematite, deposited in the pores by infiltration, forming a lean iron

ore which has been the object of some prospecting operations. The ore is too siliceous and low-grade to be of value.

The more important exposure of the Potsdam occurs south of Fowler in the middle of the limestone belt, at about 600 feet elevation. The full extent of the area is not evident, but it can be seen in force in shallow cuts just outside of Fowler on the Fullerville road. The layers are contorted and change their dip from place to place showing strong compression which may involve faulting as well. Another exposure is south of Edwards, about one-half mile from the first forks of the road, to the southeast. The sandstone is exposed along a low ridge which slopes away to the terraced flat at 660 feet contour. It is seen to be cut off on three sides by crystalline limestone. If the depression is due to an original inequality in the Precambrian surface, the latter must have been very sharply contoured. Not unlikely, it would appear, the sandstone has been down-faulted against the limestone. Test pits have been dug in certain iron-impregnated layers near the limestone contact.

Two small patches of the Potsdam are found in the area just north of Edwards. One of them lies just east of the road leading to the Northern Ore Company's mines, in the first line of ledges back from the highway, and shows a few feet of the sandstone lying directly upon the Grenville. The second is one-half mile farther north and about the same distance east from the road. Here too the sandstone may be seen to rest upon the limestone.

The preservation of these remnants within the Grenville belt may be accounted for by their sheltered position which enabled them to escape the full erosive action of the ice. That they were within reach of the glacier is shown by their polished and striated surfaces which the sandstone retains in greater perfection than any other material.

Structural Relations

Folding. The general order of succession of the major rock formations has been set forth, and it has been noted that the early Precambrian members have been subjected to powerful compressive strains under deep-seated conditions which have caused mashing, recrystallization and mineral rearrangement. Another effect of this mechanical stress is found in the changed attitudes of the rocks through the development of a folded structure which is the most constant feature of their field relations. This applies more particularly to the Grenville beds.

Fig. 2. Folding and banding of impure Grenville limestone, Edwards.

The entire series of Grenville beds shows a tilted attitude. Their inclination uniformly is to the northwest, as if they had been warped into a simple monocline along a northeast-southwest axis. The angle of inclination or dip, however, varies markedly from place to place on the surface and also along the continuation of the beds in depth. This statement is based partly on experience of the behavior of the talc deposits which have been mined to maximum depths of about 800 feet on the inclination and which show a range of from 30° to 80° in dip. It is the usual condition that a low angle at the surface will gradually steepen, and at the bottoms of the deeper shafts the dip becomes nearly vertical. This steepening of the dip is also shown in the main shaft at Edwards.

The combination of steep and changing dips leads to the inference that the beds are not of monoclinal but of much more complicated structure — a combination of closely compressed folds that have been turned over so that their wings have a common direction but not angle of inclination. The limestones and schists, it may be remarked, exhibit commonly small plications and deformations, that possibly repeat the character of the folding which has taken place on a large scale, as is the common observation in other folded regions. The effect of folding naturally is to cause duplication of the beds across the axis which is the direction of extension, and thus produce a thickness of section much in excess of the actual thickness represented in the original sedimentary succession.

It is a matter of considerable interest in connection with the mineral deposits of the district to discover the real arrangement of limestone and the associated quartzite and schists. Field work, however, has developed a modicum of information on which to base an interpretation of the structure. Records of dips and strikes of the limestone yield next to nothing about the broader relations; the marks of bedding are often obscure and with the plastic deformation which the calcareous materials have undergone it is unsafe to depend on isolated observations which over much of the area are alone available. Moreover, the erosion that followed the period of folding and metamorphism has left only the deeply buried parts of the original folds, the upward continuations if they could be projected being wholly in the air.

Under the conditions presented the only safe plan for working out the structure that may be followed is to find some persistent member of the bedded series that can be assumed to have a definite horizon and that at the same time has not yielded to pressure by

mass flowage as has the limestone. The graphitic rusty quartzite conforms to the requirements in the latter particular and not unlikely also in that of having a definite place in the succession, but unfortunately it has been broken up so much by igneous invasions as to be unserviceable for general guidance. The schists and gneisses of the Grenville are even still less to be relied upon, for they represent the maximum of change by injection and absorption.

It would seem at first blush that the southwestern part of the district, around Sylvia lake, might offer opportunity for detailed structural study. Here the limestones are fairly well exposed as they lay outside of the reach of the heavy alluvial and resorted glacial beds which cover much of the lower ground in the central and northern parts. They also hold a large proportion of siliceous impurities that apparently conform more or less closely to the bedding. The limestone belt is bordered on the northwest by a thin band of pyritous quartzite which intervenes between it and amphibolite and granite, but there is no duplication of this band on the opposite side where the limestones are directly in contact with the igneous rocks. A traverse of the belt from the one side to the other does not reveal any consistent structural relations that can be interpreted in terms of simple folding; rather the beds show confusing variations of strike and dip, indicative of a highly deformed condition such as inevitably results when the limestones are subjected to strong compression. The termination of the belt on the southwest in a broad semicircular curve, as shown on the map, might suggest the spooning out of a synclinal trough, but there is little else to support this relation.

From Talcville northeast to Edwards the belt of limestones averages about two miles wide, inclusive of the narrow band of Grenville gneiss which lies near the northern contact. A section across the valley just west of Edwards, in a northwest-southeast line reveals the following features. The beds are sharply inclined to the northwest, so far as observations permit of any definite conclusions. On the northwest side the limestone is bordered by garnet gneiss, which here is limited to a small band that has been split off from the larger area around Trout lake by granite which lies on the west and south sides. The limestone after an interval of about one-fourth of a mile is succeeded by Grenville gneiss which is interbedded and itself confined to a band of a thousand feet or so but remarkably persistent. Following the gneiss is the main limestone area one and one-half miles wide and then garnet gneiss on the footwall. The contact with the garnet gneiss is the most

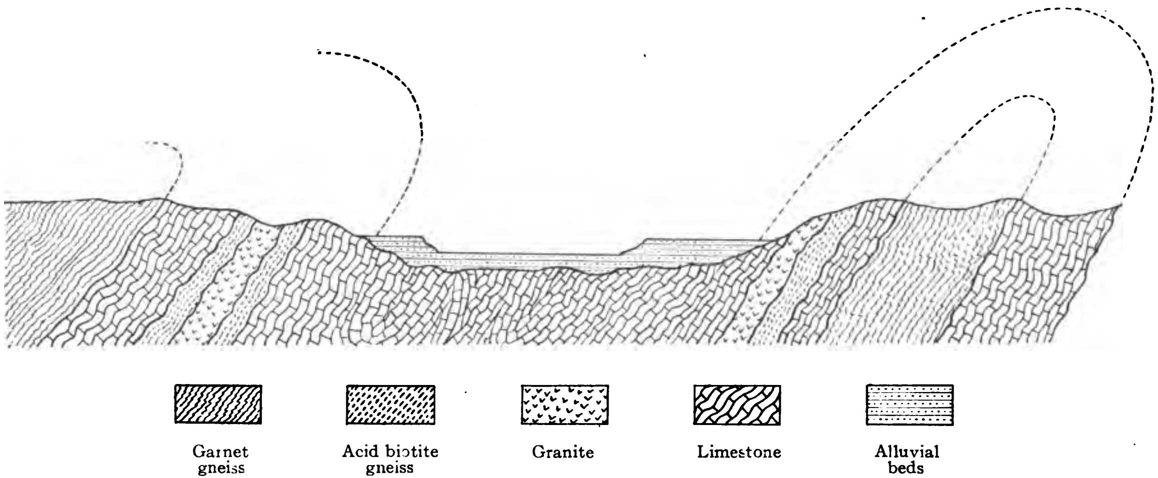

Fig. 3. Section across the limestone belt at Edwards, showing folded relations of the Grenville strata. The central belt is a syncline, bordered by compressed anticlines.

illuminative feature in the sections to which the writer's attention was called by Dr Cushing. The contact is deeply indented with the gneiss extending out into the limestone in serrated and finger-like projections, behind each of which the limestone sets back in corresponding embayments. The garnet gneiss shows a conformable dip with the limestone — northwest at a high angle — except at the ends of the northeasterly projections where they wedge out, in which place the dip swings around to the northeast before resuming its regular course. This is exactly what would happen if the garnet gneiss were interfolded with the limestone along an axis pitching northeast, with the limestone above the gneiss. The structure on the south side, therefore, appears to be a compressed anticline.

On the north side the garnet gneiss has been so intruded and absorbed by the granite as to obscure the relations, but very likely the same conditions may exist and the limestone strata on this border rise in an anticline over the gneiss to reappear again as a downfolded belt in the Gouverneur area.

The theory of structure here suggested is not put forth as a definite final explanation, but as the one which best accords with observations now available. In a region of such complexity of formational and structural detail the present maps are inadequate to work out the relationships which alone make possible a complete demonstration. It accords, however, so well with the features observed at many points as to merit serious consideration.

Evidence of minor folding in the limestones and included quartzites, schists and gneisses is to be found almost everywhere. In the hard rocks crumpling and contortion is the common condition and is plainly evidenced; in the limestones the adjustments have been accompanied by plastic deformation which has obscured to a varying extent the actual structure, though folding is to be inferred. The talc mines afford many interesting examples of contortion and plication preserved in the schistose layers. The outcrop of the talc on Wintergreen hill by the shaft of the Uniform Fibrous Talc Company is especially notable in this connection. In the railroad cut through the hill just across from this locality the limestone may be seen in a nearly vertical position with intricate folds. A small fault intersects the limestone in a north-south direction.

Reference has been made in another place to the disturbed condition of the Potsdam where this is still to be seen. The disturbance is slight compared with that exhibited by the Precambrian formations, amounting to little more than tilting in which the beds

have been moved through an angle of 5° or 10° perhaps. The remnant just east of Fowler shows fracturing and dislocation on a more marked scale, denoting a local squeeze of some importance. The beds are tilted in different directions and in places at considerable angles. The appearance of these evidences of compression in the Potsdam just at the point where the limestone itself has developed a notable constriction by the apparent inward thrust of the amphibolite seems hardly a mere coincidence; it indicates that this later development of crustal strains may have been a factor of some moment in the total deformation of the Grenville, though of course far inferior in importance to the compression in Precambrian time.

Cushing [1] has recorded the general occurrence of similar folding of the Potsdam in the Thousand Islands region. He attributes it to the broad warping of the Adirondack area in the early Paleozoic period. It would seem that the compression must have exerted some influence upon the pliant limestones, and no doubt some of the minor faulting and folding are referable to the later period.

Faulting. Examples of displacement by faults are not uncommon, though scarcely so abundant and striking in effects as would possibly be inferred from the complexity of the folding. Superficial evidence of faulting is to be had in shear zones or bands of broken and shattered materials that intersect the formations; rarely is it apparent from the relations of the dislocated parts themselves and the extent of the movement thus is seldom determinable. Shear zones are found in the hard gneisses and granite, but less frequently in the limestone. In some instances they are of notable proportions, leading one to infer movements of considerable magnitude.

Underground operations in the talc mines have uncovered many instances of minor faults, mostly transverse or at considerable angles to the strike. Only rarely are they of sufficient magnitude to cause the loss of the bed, though complicating the mining work.

Transverse faults may develop out of a secondary fold; the bed on either side of the fault plane bends around before the plane is reached and then pinches down or is lost entirely in the drag of the movement. The talc mines are noteworthy for the rolls and constrictions which develop both in the direction of strike and along the dip.

The zinc deposits have not been sufficiently developed to add much information to the subject. No instance of actual faulting

[1] N. Y. State Mus. Bul. 145, 1910, pp. 112–115.

of the ore has been observed on the surface. Two or more parallel bands of ore in such arrangement as to lead one to suspect possibly the presence of faulting are not uncommon; instances may be seen in the several bands and lenses that occur in the Northern Ore Company's property at Edwards and in the Balmat, Streeter and Dominion Company's deposits near Sylvia lake. The Edwards mine is based on two groups of deposits separated by an interval of about 600 feet in the direction of the strike and slightly across the dip. In the southwesterly group two distinct bands appear at the surface and a third one was encountered in exploration with the drill which seemingly does not outcrop. All these, however, are certainly separate bodies and it appears equally certain that the northeasterly group is also independent and not a displaced part of the southwesterly ore zone.

In the Brown shaft at Edwards, which is sunk on the dip of one of the outcropping bands of the southwesterly zone, the existence of a considerable displacement is inferred from the conditions there encountered. The band of ore is mainly developed on the south side of the incline and has been worked by means of a series of levels, the lowest being 500 feet on the slope. In following the ore to the south the levels gradually turn from southwest to south and then to southeast, the strike at the sides being at right angles to that in the incline. The ore terminates abruptly against a band of weathered soft water-soaked material which cuts across the ore at right angles or in a northeast-southwest direction. The soft material is of talcose nature. A drill was put through the band to explore for the continuation of the ore but encountered blue clay, no doubt the alluvial clay from the adjoining valley. This may indicate that the eastern margin of the hill is marked by a longitudinal fault. There is still a possibility that the soft rock is simply the weathered edge of the limestone ridge and not the result of displacement. I am informed by W. D. Blackmer, superintendent of the mine, that a fault has been uncovered on the northeasterly end of the ridge in the workings of the White shaft.

OCCURRENCE AND CHARACTER OF THE ZINC DEPOSITS

Distribution. The zinc ores of the Edwards district are enclosed by Grenville limestone. Most of the occurrences thus far brought to light lie within the main body of limestone in the stretch of 10 miles or so between Sylvia lake and Edwards. The sketch map

figure 1 shows the approximate location of the discoveries reported up to the year 1917. Further exploration may extend the bounds of the ore-bearing territory, since the same Grenville strata continue in smaller belts to the northeast and southwest of the district as at present defined, with similar surroundings. Owing to the fact that most of the limestone outcrop is concealed by soil and modified glacial materials prospecting has been carried on under some disadvantage, leaving room for further discoveries inside and outside of the known productive area.

The association of zinc ores with limestone is common; in fact most of the productive mines throughout the country are based on deposits illustrative of this relation. On the other hand some extensive bodies are enclosed by other kinds of rocks, so that no conclusive argument can be drawn from occurrences elsewhere as to the probable limits of the ore distribution in the Edwards region. What is of more importance in that particular is the method of origin of the ores. This subject will be considered at length in another place, and here it need only be remarked that the deposits do not belong to the type of veins which would involve their accumulation in preëxisting fissures of size commensurate with the ore-filling. If such were the case it would be quite possible to have the ore bodies extending into the adjacent schists and granite, if suitable fissure zones were provided for the circulation of the metallizing solutions. The evidences, however, all go to prove that ores were formed by a process of replacement, while the country rocks were deeply buried and under such pressure that extensive openings probably could not exist. Limestone offers the most congenial environment for this type of zinc deposits, and it is not at all likely in the presence of a great mass of limestone that the metallizing solutions would extend their range of activity into the more resistant formations.

Attention has been called to the pyrite deposits which occur in the Grenville quartzites and schists associated with the limestone. They bear some resemblance in regard to general features, such as age and probable secondary origin, to the zinc ores, and if zinc blende were to be found outside of the limestone it might well be looked for in them. Yet they are destitute of zinc except for an occasional grain that may occur in the ore, but more especially in vugs that are lined with crystallized blende and quartz as shown in samples from the St Lawrence Pyrite Company's mines at Stellaville.

In their areal distribution the zinc deposits do not conform to any particular stratigraphic horizon of the limestone. Of course in view of the uncertain structural relations in the district, the real position of the ores in the limestone can not be stated; but under any conditions of folding and tectonic disturbance that can readily be conceived it would be quite impossible to bring the several bodies into stratigraphic alinement. Thus in the Northern Ore Company's property at Edwards not less than four distinct bodies occur, separated by varying intervals of limestone, and as many or more are known in the vicinity of Sylvia lake.

The ore localities are grouped mostly along the margin of the limestone belt or else in the vicinity of injected bands of gneiss included within the limestone. In many places they occur close to the contact, that is within 200 or 300 feet of the latter, as is the case at Edwards and at the several openings on the Webb and McGill farms south of Edwards, and the Streeter property east of Sylvia lake. A few lie farther out in the limestone. On the whole it can be stated quite definitely that the contact region is most favorable to the occurrence of the ores.

Another feature of their distribution is connected with the silication of the limestone. The presence of large amounts of secondary silicates — tremolite and diopside and their alteration products — as well as vitreous and cherty quartz is generally to be noted in the vicinity of the deposits. In view of this feature it would seem reasonable to expect a rather close relation physically between the talc beds and the zinc, and in fact many of the occurrences do exemplify that relation. The fact that ore has rarely been discovered directly as the result of mining operations for talc is ascribable very likely to the general practice current throughout the district in exploring and working the material. It is the common custom to follow the talc from the surface without any preliminary dead work. A shaft is sunk within the talc and as a rule follows the bed however it may vary in dip all the way down; drifts are opened at intervals on one or both sides of the shaft and these also keep the course of the bed. It is rare thus that the workings extend into wall rocks, the only necessity for this occurring when a sharp fold or fault displaces the bed. There is a minimum of opportunity therefore to discover the presence of ore in the hanging or foot walls, however close the two minerals may be associated.

Specimens of blende were found by the writer in the waste rock of one of the Talcville mines. On inquiry it was learned that the

rock came from an exploratory opening in the hanging wall, which had been made in the attempt to follow the pinched and faulted bed encountered on one of the lower levels. Such a discovery, of course, is a mere accident.

The occurrence of the sulphide bodies in the impure beds of limestone heavily charged with silicate minerals is in keeping with what might be anticipated from purely physical grounds, if the ores had been introduced subsequent to the process of silication. The texture is likely to be more open, with a freer passage to circulations, among such beds than in the high carbonate rocks, since the cohesion between grains of different minerals is not so close as between grains of uniform character. An additional factor that may enter into consideration is the hydration of the silicates with consequent change of volume, should this have begun before the introduction of the ores, which is not at all improbable. It is a familiar fact that serpentinous rocks are very often poorly bonded, showing numerous cracks and seams open to weathering agencies.

Shape of the deposits. In shape the ore bodies show too much variation to be characterized by any general term. On the surface they appear as bands or stripes, and as indefinite patches; the richer ores usually occurring in rather sharply defined bands, while the disseminated blende has an indefinite line of demarcation, shading off into the country rock. The outcrop of the bands may appear in narrow limits to have the regularity of veins with parallel walls, but in a large way the ore pinches and swells and winds around quite without rule. In one or two localities the ore seems to have the form of a relatively thick lens or shoot.

The only satisfactory exposures of the deposits underground are to be had in the mines of the Northern Ore Company at Edwards. The body explored by the Brown shaft outcrops as a band of mixed blende and pyrite with sharply defined and parallel walls. It is about four feet thick at the surface, but gradually increases on the dip and on the 200-foot level bulges out to fourteen feet after which it again diminishes. It is still in evidence on the 500-foot level. The longest drift on the ore body is 600 feet.

The form of the body thus appears to be an attenuated lens, modified by rolls and pinches, while it is also warped out of plane in a broad arc which curves around through an angle of 90° so that the strike changes from northeast on the north end to northwest on the south end.

The contact of ore and limestone in this deposit is usually sharp and distinct, without any real gradation from the one to the other.

The only noticeable difference in the ore of the interior and of the margin is that near the border it has a somewhat larger proportion of gangue in the form of silicates.

In mining it is often observed that the ore comes away from one side cleanly, giving a smooth limestone wall without any inclusions of sulphides, while on the other side the contact is frozen, and stringers and wisps of ore may make off into the limestone for some distance or small blocks of limestone may be embedded in the sulphides. There is some semblance to gradation in the latter case. On the free side a selvage of talcy decomposition products may intervene between the country rock and ore and provide passage for water (see fig. 7).

The ore body opened by the shafts on the north end of the property has some points of contrast with those just described. As seen at the surface it consists of an irregular zone of the limestone heavily charged with serpentine, carrying blende and pyrite in bunches and disseminated grains, very unevenly distributed. Every gradation from serpentinous limestone to solid sulphides with very minor amounts of serpentinous gangue may be found. The zone is elongated parallel with the strike of the wall rock and measures fifteen feet or more across in the widest part. Underground it is said to have the form of a broad lens or shoot. The ore shows brecciation and the fragments have been recemented by vein serpentine and calcite. The effects of compression are also evident in striated and slickensided surfaces.

The shoot form is also exemplified in the upper portion of the deposit on the Dominion Company's property near Sylvia lake. The outcrop of the body consists of soft hematite which was exploited years ago in connection with the Fullerville furnace. The old opening revealed a mass of hematite of rounded section plunging downward at a fairly steep angle. When the workings were entered it was found that the hematite gave way within a short distance to a mixture of harder hematite with unaltered sulphides of iron and zinc. The latter ore has a fine texture and is very tough and hard.

It would appear that the oxidation of the sulphides at the surface had resulted in the formation of soluble compounds of iron and zinc which had been carried down and reprecipitated in contact with the original sulphides to form the mixed ore.

In the disseminated type which seems to be more characteristic of the deposits in the interior of the belt, the mineralization shows,

no well defined boundaries against the limestone but shades off to the barren rock. In some places the sulphides are arranged along a band which follows the bedding more or less closely, and again they are mere clusters or wisps which occur here and there without reference to any structure of the limestone. There has been little effort made at the exploration of such deposits and it would appear rather speculative to attempt to estimate their importance. The sulphides are in fine particles, usually much smaller than in the other type of deposit, so that their concentration will offer increased difficulties over the richer ores.

DESCRIPTION OF THE ORES

Physical character. The ore is characterized by a compact even-grained texture, with few free openings or vugs such as are found in ores occurring in open fissures. The mineral particles are in close contact, leaving only the small pore spaces that exist in every rock no matter how compact.

Both blende and pyrite are developed as rounded to subangular grains, never as well bounded crystals. Rarely the pyrite may be seen to have one or more plane surfaces that correspond probably to crystal faces. The blende, so far as observed, shows no tendency of this kind, though its essentially crystal structure is evidenced by its cleavage. The two minerals are approximately of the same average size in a single hand specimen, though occasionally the one or the other may develop unusual proportions.

The grain varies considerably in the different occurrences. It is generally coarser in the high-grade ores, such as are exemplified by the well defined bands or lenses, than it is in the disseminated leaner ores in which the sulphides are scattered through a ground-mass of carbonates. In the latter the grain diameters are of the same order of magnitude as those of the non-metallics, whereas in the richer ores they are apt to be much larger. The variation between different deposits in this respect is very marked. Samples of rich blende from Edwards show individual cleavage surfaces an inch or more in diameter; the pyrite, of which the proportion is usually small in the highest grade ore, is inclined to be more finely divided and usually does not exceed one-fourth of an inch in diameter. In the disseminated ores the ore particles range from one-eighth of an inch in the coarser phases to mere dust-like particles visible only with the lens.

A general absence of banding, crustification and similar vein structures are to be noted for all the deposits that have been so far uncovered. This feature is believed to be a primary one, essential to the conditions under which the metals were deposited. There is no indication that such structures were once present and were afterward obliterated by compression, as might be conceived to be a possible condition. The evidences, so far as they go, tend to support the view that the ores as a whole have not undergone any thorough modification or rearrangement since they were laid down in their present places. It is not to be implied that they have escaped wholly the influences of compression and metamorphism; on the contrary they were subject to such influences for a long period during which the deposits were still deeply buried under the load of overlying crystallines and the later one when they were covered by a considerable thickness of Paleozoic strata; but these influences were not of such magnitude as to produce a general breaking down and recrystallization of the metallic minerals, as would have resulted had they been deposited in the unmodified limestones and had participated in all the vicissitudes of metamorphism, igneous and regional, that the wall rocks have undergone.

Locally the ores do show pressure effects and a certain amount of mineral rearrangement. For example, the northerly deposit on the Northern Ore Company's property near Edwards, where exposed in the surface open cut, exhibits breciation and differential movement which may be referred to regional forces. The fragments of sulphides have been recemented by infiltration of carbonates and serpentines along the boundaries which are sometimes smoothed and striated by the displacement of the fragments. The small prospect on the cemetery lot near Balmat Corners shows similar features. Here it would seem also that the sulphides themselves have undergone more or less recrystallization under compression, for the pyrite and blende occur in separate aggregates made up of unusually large particles, instead of the usual intimate intergrowth. The presence of secondary rhombohedral calcite and vein serpentine in this occurrence establishes the participation of mineralizing agencies which may well have operated in the modification of the sulphides.

Just how much of a factor regional forces have been in the production of these phenomena may be open to question. An alternative explanation for them may lie in quite another direction, that

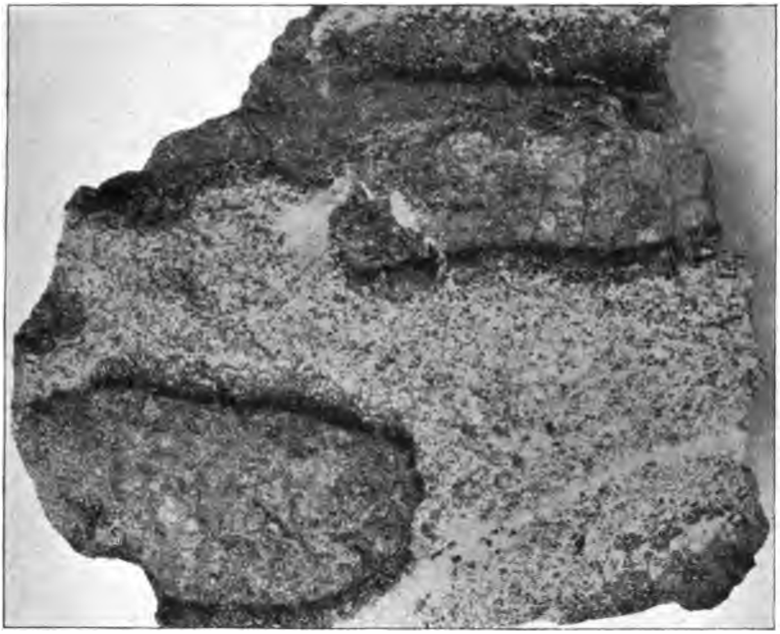

Fig. 4. Nodules of talc with serpentine rims in the ore-bearing limestone. Smaller grains of serpentine disseminated throughout the rock which carries sulphides so as to form a lean ore.

is in the pressure developed by the hydration of the accompanying silicate minerals. It is noticeable that in the instances where crushing is most evident the ore is found in a particularly impure limestone with a large proportion of secondary talc and serpentine. The change from tremolite and diopside to talc and serpentine, which is the usual course taken in alteration of the silicates, would involve a volume increase of very considerable proportions in the impure layers. Yet it seems to the writer that the pressure phenomena have been largely caused by external mechanical agency.

Scattered particles of silicates may always be found in the ore, even the richest, and sporadically there occur bunches and nodules of larger size, from a few inches to a foot or more in diameter. The smaller particles are quite irregular showing deep indentations and protuberances which are matched by the embedding sulphides. In the limestone the same minerals occur but always with more regular boundaries, often in prismatic crystals. The larger nodular aggregates have a rounded form which is much the same as that characterizing their occurrence in the wall rock. These aggregates are made up usually of silicates in process of alteration to talc and serpentine. The sulphides surround but do not penetrate to any depth into them. The relations uniformly are such as to indicate that the metallic minerals were deposited after the metamorphism which resulted in the formation of the silicates.

Mineral and chemical composition. Mineralogically the ores of the Edwards district are complex. They consist of a combination of metallic ingredients — sphalerite and pyrite chiefly — with the non-metallic substances dolomite, serpentine, talc, barite and quartz as gangue. In addition galena occurs in small amount in all the ores and occasionally as a rather important constituent.

The blende or sphalerite is commonly a dark brown to black submetallic variety, which betrays the presence of considerable combined iron. It is typical black jack of the western mines. In thin section it has a reddish brown to yellowish brown color, translucent to almost opaque. An analysis of a picked sample of the characteristic blende from the Northern Ore Company's mine, made in the laboratories of that company, gave the following results for the chief constituents: zinc, 60.61%; iron, 4.91%; sulphur, 32.73% — sum. 98.25%. This corresponds to 90.32% zinc sulphide molecule and 7.73% ferrous sulphide molecule, reckoning all of the iron in that form, with .20% sulphur in excess. It is probable that some of the iron

should be calculated in terms of pyrite rather than the monosulphide, but a small excess of sulphur is demanded no doubt for combination with lead and other metallic elements. It would appear that the blende normally carries 4 or 5% of metallic iron.

Among the elements present in the blende in very small amounts are cadmium and manganese. As a rule their presence is limited to mere traces. There is little or no silver, at least in those ores that have been subjected to careful test.

A lighter colored, translucent blende, of strongly contrasting appearance to that of the usual ore, occurs sporadically in the district. It forms separate aggregates as a rule, rarely accompanying the darker mineral. Its presence was first noticed in the output of the Brown shaft at Edwards where it appears in small quantity apart from the regular ore. Seen in the mass its appearance is distinctive, not only on account of its lighter color and nonmetallic appearance, but by reason of the numerous roundish inclusions or nodules which it holds. These inclusions are white in color and produce a mottled effect. They consist of carbonates, chiefly dolomite, in rhombohedral grains that seem to have been deposited as a filling of open cavities, such as are not seen in the normal ore. This suggests a separate and later deposition of this variety of blende, under shallow cover, and possibly by ground water circulations. It is noticeable that this ore has a finer grain and is less pyritic than the normal variety.

In the average ore of the district pyrite always is a prominent constituent. Its proportion varies considerably between different deposits and also in specimens from the same deposit, but in a large way it represents probably from one-fourth to one-third of the metallic ingredients. At Edwards the pyrite product is stated to be about one-half that of blende. The mineral occurs in disseminated particles, usually evenly distributed through the mass. In size the particles approximate those of the blende. Specimens of the richest ore from Edwards, which carries 40% or more zinc, show small grains of one-eighth to one-fourth inch in diameter surrounded by coarse blende with cleavage faces an inch or so across. The more common relation, however, is a granular intergrowth of the sulphides in nearly equidimensional particles with dolomite and serpentine.

Galena seldom appears in visible particles, but it is probably present in all the occurrences to the extent of a fraction of a per cent at least. In the mines now worked near Edwards it is occa-

sionally observable in the hand specimen, and its general presence becomes very evident during the process of mill treatment, inasmuch as the concentrating tables always show a small band of grayish color above the brown blende. At the north shaft at Edwards specimens were picked from the dump which showed cleavage pieces of galena an inch or so across, surrounded by the blende. Such large aggregates may be the result of secondary deposition. On the northeast side of the Balmat property a tunnel and shaft have been driven to explore a body of blende, galena and pyrite. This is the only occurrence so far discovered that contains a large proportion of lead, which here approaches nearly that of the zinc, while the pyrite is almost as abundant as the two together. The galena is in irregular or rounded grains like the blende and seems to be of the same period of deposition. It is said to contain a small amount of silver which was the incentive for the early exploration of the deposit which was undertaken about 1840. The deposit is not well exposed and it is impossible to obtain much information about its form or extent from the present workings.

Barite occurs in small amount. It was first detected by the writer in the weathered crusts which marked the outcrop of the Edwards deposits. The crusts which consisted of limonite filling or cementing a porous aggregate of silicates, largely serpentine, showed here and there grains of a whitish translucent mineral which was found by chemical tests to be barite. It has not been identified in the thin section, though analysis and mechanical separation of the Edwards ore shows it to be present to the extent of from 1 to 3% in the run-of-mine product.

The other accompaniments of the ore are quartz, carbonates and silicates, which are the chief constituents of the country rock. They call for no separate mention at this time, but have interesting relations to the paragenesis and origin of the sulphides.

The chemical features of the ores are illustrated by the following analysis representing samples from the Northern Ore Company's mines at Edwards. No. 1 and No. 2 were made in the laboratories of that company for commercial purposes; they represent the average composition of the mine product over periods of a month each. No. 3 is an analysis of a picked sample of ore from the south shaft which is on exhibit in the State Museum. It was made by R. W. Jones in the Museum laboratory.

	1	2	3
SiO_2	21.47	18.52	5.60
Al_2O_3	4.17	12.12	.36
CaO	9.34	11.76	1.45
MgO	13.17	15.04	.61
BaO	a 2.75	a 1.52	1.46
CO_2	n. d.	n. d.	n. d.
H_2O	n. d.	n. d.	n. d.
Zn	21.47	18.52	51.43
Fe	8.50	8.46	5.80
Pb.	.125	.197	tr.
S	19.006	17.18	30.86

a. $BaSO_4$

Cadmium and manganese were also indicated in minute amounts in analysis No. 3; also small quantities of CO_2 and H_2O. The presence of free quartz in all the samples is shown by the excess of SiO_2 over the amounts required for combination with the bases — MgO, CaO and Al_2O_3 — present as silicates.

The ore outcrop. The common surface indication of ore is an iron-stained area in the limestone which is apt to be somewhat depressed and softer than the surrounding material. The iron-stain is caused by limonite which results from oxidation and hydration of the iron present in the sulphides. It may consist of an impregnation of limonite through the rock or of a considerable deposit of this ore in soft ochreous form. In a few places the outcrop carries a heavy gossan of cellular or massive limonite in fairly pure state. In any case the weathering that is responsible for the formation of this kind of cap is of shallow extent and has taken place recently, after the uncovering and freshening of the ore by glacial erosion.

The depth of the limonite deposit ranges from less than one inch to several feet, depending upon the topography and depth of soil cover. On high ground, where there is little or no soil, the deposit is thin, since the tendency is toward the removal of the decomposition products as rapidly as they form. In low ground the limonite does not extend to a depth of more than three or four feet as a rule, and if the outcrop is covered by alluvial clay or hardpan it may be still less.

The shallowness of the weathering is not exceptional for sulphide ores in glaciated regions, but contrasts strongly with the usual condition in more southerly latitudes, where sphalerite seldom occurs until the level of permanent water is encountered. Above that level the zinc occurs in the oxidized forms of smithsonite and calamine.

The oxide compounds have no commercial importance in the Edwards district, although the presence of smithsonite may be mentioned as a matter of mineralogical interest. It is found as a white coating or film on the sulphides under the limonite stain. It is accompanied rarely by a greenish yellow substance, also of secondary nature. This has an earthy texture and shows a reaction for cadmium. Greenockite seems to be its closest relative among the recognized cadmium compounds.

A singular variation to the normal course of weathering as outlined is supplied by the occurrence near Sylvia lake that has been under exploration recently by the Dominion Company. The body of sulphides has a capping of hematite of both hard blue and red varieties and was first worked as an iron mine. A little vein quartz is associated with the iron, but nothing in the surface ore is suggestive of the presence of zinc below.

At a depth of 75 feet or so the hematite lost its homogeneity and both blende and pyrite along with the usual hydrated silicates began to appear. The iron oxide and secondary quartz occur in this mixed zone as infiltration in the small cracks and interstices of the ore. Still deeper down the sulphides greatly predominate and the hematite shrinks to small amount. It would appear that the hematite has resulted from oxidation under quite different conditions than those which obtain at present and which result in the formation of a limonite gossan. The depth of the oxidized zone is also exceptional for the district.

The conditions seem to find explanation on the basis of preglacial weathering, when the ore was probably capped by a sedimentary mantle and lay at some depth from the surface. The occurrence of hematite along the contact of the Grenville limestone and Potsdam sandstone has already been remarked. The occurrence may well have found frequent counterparts before the advent of the ice, but elsewhere the glaciation sufficed to remove the oxidized materials.

PRESENT AND FUTURE STATUS OF MINING

The single actual shipper of zinc ore so far in the district has been the mine of the Northern Ore Company, just outside of Edwards village. It was the first undertaking in which a consistent plan of campaign, with liberal financial support, was applied to the exploration and treatment of the ores and its career after emerging from the preliminary experimental stage, incident to almost every new mining district, has been attended with signal success. The beginning of ore shipments in the spring of 1915 coincided with the inauguration of an exceptionally prosperous period in the metal industry, so that the company started under specially favorable auspices, that will not be shared probably by other enterprises in the district. The mine has already established itself as one of the important producers of zinc ore in the country.

The success of this undertaking, and especially the outcome of the deeper mining and exploratory operations which the company has had under way, have been awaited with a good deal of interest by those owning properties in other parts of the region. The conditions are new, at least different from those in the zinc districts which have contributed the main part of the production, and nowhere have similar occurrences in the metamorphosed and folded Precambrian limestones received a thorough investigation from a mining standpoint. To maintain a conservative attitude toward the district during the test period of operations was the wisest policy.

It may be regarded as a principle, now well established by results of exploration as well as by geological considerations, that the mineralization is not confined to the superficial parts of the limestone belt. This should not be interpreted in the sense of an assurance of the continuity of the ore in any single deposit — for that is decidedly overstating the matter — but it does mean that there is no apparent lower limit within the limestone where the ore deposition as a whole terminates. The depth to which exploration may be conducted with possible success will be governed by local conditions to a great extent, inasmuch as the mineralization no doubt originally depended upon certain favorable combinations of chemical, physical and structural characters which can only be interpreted in each special instance; yet broadly considered the middle or lower reaches of the limestone strata offer equal opportunity with the upper for the discovery of valuable ore deposits.

It is precisely this condition which holds encouragement for the future of zinc mining in the Edwards district. Large bodies that

Fig. 5. View of Northern Ore Company's Mine, Edwards. Ridge of mineralized limestone in background. No. 1 shaft at left of mill.

individually might afford a basis for a durable mining industry have not been found so far, and in the writer's opinion may hardly be anticipated anywhere in the district. The mineralization has not been localized in the same way, for example, as that which was accountable for the great deposits in the Precambrian limestone of northern New Jersey. Instead it has given rise to many separate bodies, distributed over a considerable area and a corresponding range of depth, the combined resources of which are likely to prove quite substantial in view of the record so far made in their development.

INDIVIDUAL DEPOSITS OF THE EDWARDS DISTRICT

The Northern Ore Company's Mine, Edwards

Geology. The ore bodies on which this company is now at work outcrop in a low ridge of limestone, three-fourths of a mile north of Edwards village. The ridge forms the first rise of ground across the alluvial flat or flood-plain of the Oswegatchie after it enters the valley from the south. This flood-plain of reworked glacial materials — mainly silts and clays — is no doubt underlain by a limestone, but for an interval of half a mile or so the rock is completely concealed. Limestone outcrops within the valley further northeast and off the Gouverneur sheet.

The limestone ridge is an isolated hillock, that lies in an embayment of Grenville gneiss. It is some 1200 feet long in a northeast-southwest direction, having a well-rounded oval contour and rising 40 or 50 feet above the Oswegatchie flat. On all sides but toward the southeast the limestone is bordered by gneiss, with the contact concealed under a glacial filled depression that follows the curving contour of the base of the ridge and opens out at the ends into the main valley.

The gneiss itself belongs to a narow band, scarcely more than a few hundred feet wide in most places, that parallels the northern contact of the main limestone belt for several miles southwest of the mine. Between it and the granite and amphibolite border is an interval, a quarter of a mile wide possibly, that is occupied by limestone. Just northeast of the mines, across the Trout lake road, the gneiss band bends around to the east, heading off the ore-bearing strata and terminates in a blunt knob that is all but surrounded by limestone.

The relation of the gneiss and the limestone, so far as they can be ascertained, are those of an interbedded series. No uncon-

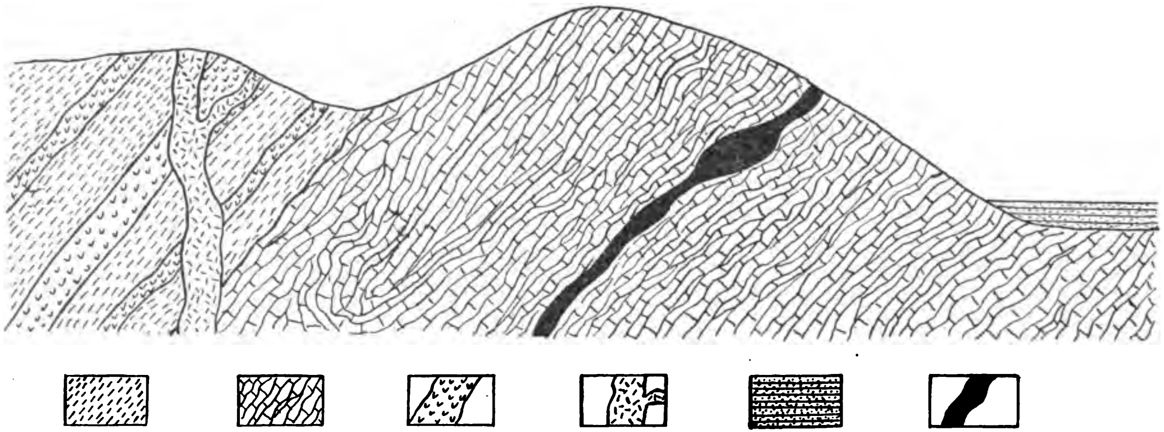

Fig. 6. Geological section at No. 1 mine of the Northern Ore Company, near Edwards.

formity is apparent, although the sudden change in the trend of the gneiss and its abrupt termination, as just described, are not in keeping strictly with what would be expected of a conformably bedded arrangement. It is to be borne in mind, however, that the strata have been subjected to powerful compression and that the limestones and the hard gneisses have reacted quite differently under the stress. The dip and strike of the limestones, where their bedding is determinable, shift about in a way which can hardly be interpreted on the basis of simple folding, but represents undoubtedly an accommodation to pressure by plastic deformation combined with sharp flexures. Considered broadly, however, the general attitude of the limestones is that of a bedded series which strikes northeast-southwest parallel with the main structural trend and dips northwest at an average angle of 45° or above. This is the attitude of the gneiss, also, below which the limestone extends on the dip.

The character of the gneiss, a dark hornblende-biotite variety, often graphitic, has been described in the section devoted to the general geology of the district. In the immediate vicinity of the mines it contains a large amount of granitic material owing to injection and diffusion of the magmatic juice from the red porphyritic granites and to intrusive bands and bosses of this rock which occur in great abundance. Quartzitic layers and occasionally a band of limestone are intercalated with it. Information of the general character and relations of the gneiss is obtained from the log of a diamond drill hole put down by the Northern Ore Company on the White property, well within the gneiss outcrop. The section in this hole, as interpreted by Cecil Pocock, former mining engineer for the Northern Ore Company, is as follows from top to bottom:

Rock	*Feet*
Gneiss	0–153
Granite	153–170
Granite with gneiss inclusions	170–233
Limestone	233–325
Quartzite	325–342
Granite with some gneiss	342–473
Limestone and quartzite	473–566
Gneiss	566–715
Limestone and minor beds of quartzite	715–935

The contact of the granite injected gneiss with the limestone shows alternations, as might be expected from an interbedded

series. The main contact between the hard rocks and the limestone comes at 473 feet. The quartzite that is included is largely a grayish finely granular rock, not the vitreous or cherty kind which veins the limestone.

Ore deposits. The ore bodies now developed embrace three distinct occurrences, locally called veins, of which No. 1 and No. 2 are in the southwest part of the hill and tapped by the Brown shaft, and No. 3 lies northeast about 600 feet, with the Williams and White shafts as surface openings. Access to the latter deposit is now maintained through the fourth level of the Brown shaft by a 600-foot connection following the general strike of the limestone, and all the ore is raised through this shaft.

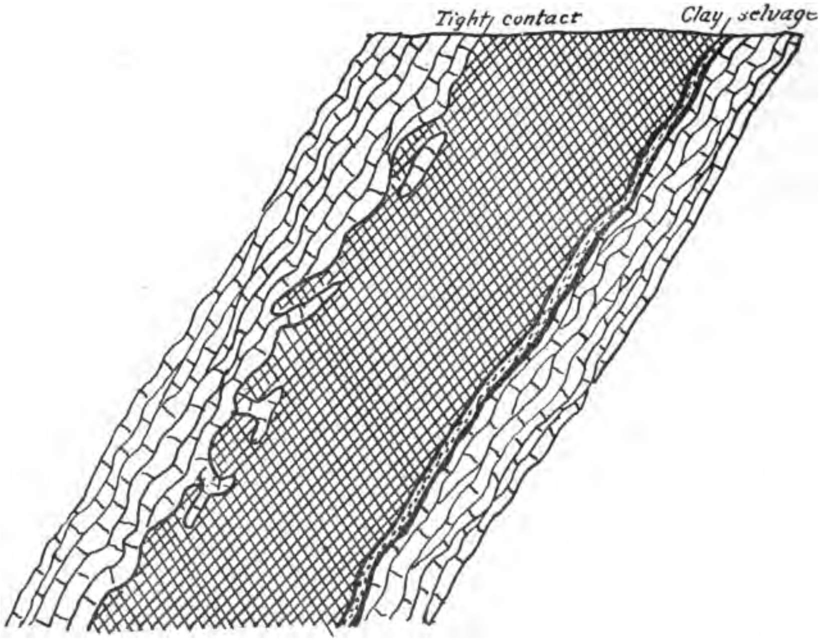

Fig. 7. Relation of ore and limestone in No. 1 mine, Northern Ore Company.

In shape the two southwesterly bodies may be described as broad attenuated lenses which in their limited outcrop appear as bands with parallel walls. Their well-marked boundaries against the limestone on the foot and hanging lend the appearance of fissure fillings or veins, but against this view of their character may be cited the evidence of replacement to be found all through the ore and the lack of any continuous selvage along either wall. Both bodies are warped out of place, No. 1 being arched toward

the hanging side in a semicircular curve, and No. 2 warped to a less extent. They vary greatly in thickness both along the dip and on the strike. On the outcrop No. 1 was about four feet thick and No. 2 a little less. In depth they swell up to 12 or 14 feet in rolls which are succeeded by pinches which may constrict the ore to a foot or less in width.

The White or No. 3 body is not so well defined on the surface as the others; its outcrop consists of a zone of the limestone 15–20 feet thick that carries bunches and disseminations of sulphides intermixed with much serpentine. The ore is distinctly brecciated in places. In depth the deposit is reported to develop a bulge or shoot-like form which is perhaps the result of a cross-fold.

The underground connection between the Brown and White workings provides a good exposure of the limestone beds which at the surface are considerably weathered and only on view in a few places. I am informed that no structural break of any importance appears in the interval.

An outlying ore occurrence, on the trend of the lenses just described, appears across the Trout lake road, 400 feet or so northeast of the White mine. It has been prospected by a shallow opening which is said to have encountered gneiss at the bottom. This rock appears on the surface within a few feet and apparently the limestone wedges out against it. The small quantity of ore that has been exposed in the pit consists of the usual mixture of sphalerite and pyrite, with a preponderance of the latter. The structure at this point is a matter of interest that is not altogether clearly revealed by the exposures. The limestone is broken up so much that its attitude can hardly be deciphered. Its discontinuance by wedging out along the strike and as it were spooning out on the dip, however, agrees with the conditions of a minor synclinal fold compressed between the hard gneiss. The latter has been subjected to a great deal of granitic injection.

Grade of the ore. The ore of these deposits is characterized by almost complete replacement of the carbonate minerals, so that the grade averages high. Still the tenor of zinc fluctuates considerably, with the varying proportions of pyrite and other ingredients. The actual average of the run-of-mine may be taken at 18-20% zinc, according to the mill sampling for monthly periods. This indicates a sphalerite content of 25% or slightly more, after allowance for combined iron. The tenor is usually lower than would be inferred from inspection of samples, since there are always small inclusions of unreplaced silicates even in the most massive ore.

The pyrite in a large way averages about one-half the percentage of sphalerite. It fluctuates more widely than the latter; in some places it ranks on a parity with the blende and in others it is practically absent.

Mine operations. The method of mining that has been employed hitherto, combines exploration with ore extraction. It consists in sinking an incline on the dip of the deposit, following the deviations so as to keep within the ore, and the opening of a series of drifts or levels at intervals of 50 or 100 feet. The ore is then broken down by overhead stoping. The limestone provides a good roof, and the stopes can be carried wide with little timbering.

Water is encountered in all subsurface workings, and its disposal may prove more or less of a problem if mining be carried to depths of 1000 feet or more. The water is a part of the normal underground flow which enters from the higher ground on the valley rim, much of it probably along the gneiss contact. It penetrates along the joint and fissure zones probably to great depths. The new vertical shaft of the Northern Ore Company encountered a heavy flow at around 400 feet. Adequate provision for pumping and attention to the matter of sealing off the main channels as they are encountered, are the only means for dealing with this difficulty. It is well to recognize that every mining enterprise is certain to encounter this problem.

Concentration. All the ore is concentrated before shipment. The milling process involves a combination of gravity and magnetic methods, which is rather novel for the treatment of zinc ores. The application of magnetic separation on the raw ores is only possible for sphalerite which contains enough combined iron to render it permeable, which is the condition of the dark semi-metallic product of the Edwards district.

The details of the milling practice will not be entered upon, but it may be stated that the general plan substantially is to crush the ore and then subject the various sizes to preliminary wet concentration with jigs and shaking tables. In this way the non-metallic ingredients are eliminated. The mixed pyrite-sphalerite concentrates are then treated without roasting by magnetic machines of high polarity which effect a separation of the two ingredients, yielding a commercial pyrite product as well as one of zinc.

The Webb Farm, South of Edwards

To the south of Edwards, the first showings of ore are found on the Woodcock, Webb and McGill places, situated on the Fullerville

road. The deposits lie along the southern margin of the limestone belt, across the valley from the Northern Ore Company's mine, from which they are about two miles distant in a straight line. The existence of zinc in this vicinity was first brought to notice by A. J. Moore, formerly of Edwards, who did some prospecting there in 1914. More recently the Lux Development Company has been engaged in exploring the outcrops on the Webb place.

The ore in this section occurs along a restricted zone within the limestone, following the strike of the beds and keeping close to their contact with the gneiss. The latter is a gray, garnetiferous often rusty rock that is banded and injected by granite. It belongs to the Grenville series and here lies below the limestone, both rocks having a northerly dip at a high angle. The peculiar relations which characterize the contact in this vicinity have been noted in the discussion of the structure of the limestone belt.

The ore is found as disseminations and richer bunches, which show no sharply defined boundaries toward the country rock, but rather grade off on the edges. The sphalerite may be scattered through a band of limestone 6–8 feet wide, but in a very uneven way. Altogether the outcrops and prospect holes — none of these more than a few feet deep — occur over a distance of 800 feet along the edge of a ravine which has been eroded in the limestone on a northeasterly course.

The sphalerite is lighter in color than the ore of the Edwards mine of the Northern Ore Company, but it contains more or less iron. It is admixed with pyrite, so as to form a granular mixture of rather fine texture; occasionally pieces of coarse blende nearly free from pyrite occur, as at Edwards. In all the ore there is considerable gangue stuff in the form of serpentine and talc nodules and unreplaced carbonates. There is so much variation that it is difficult to estimate the average tenor.

The exploratory operations have been confined to the sinking of shallow pits or shafts in three or four places. While much of the ore is of commercial grade in regard to zinc content, the quantity so far revealed is hardly sufficient to afford a basis for mining.

McGill Farm

This adjoins the Webb place on the northeast, lying along the same ridge of limestone, close to the gneiss. The occurrence of ore is manifested in outcrop at a distance of 1000 feet or more from the most northerly opening on the Webb place. At the time of the

writer's visit, in the fall of 1916, little had been done to prospect the deposit. The sphalerite is found as a dissemination within a layer of the limestone some 4 or 5 feet wide and of uncertain extent on the strike. There is little admixture of pyrite and the ore has a light brown color, significant of a minimum of combined iron. The dip of the ore band seems to be about 30° northwest. There is much serpentine in evidence and on the hanging side a little slip-fiber asbestos.

Woodcock Farm

Continuing along the gneiss contact scattered occurrences of sulphides may be seen or are indicated by the rusty honeycombed appearance of the limestone. Two or three exposures have been made by blasting in which 6–8 feet of limestone more or less charged with ore has been uncovered. The gneiss lies scarcely 50 feet away. The limestone beds in this locality are ribbed by narrow bands of white vitreous quartz, so prominent in the Sylvia lake region. The occurrences stretch over a distance of 300 feet or more.

Balmat Place

This lies just north of Balmat Corners on the Fowler road and one-half mile east of Sylvia lake. It is probably the first property in the district to have been prospected, as there is mention of the exploration of one of the bodies which it contains in the report by E. Emmons relating to the First Geological Survey in 1838. Emmons refers to the property under the name of *Belmont* and from his description it is evident that the object of the early search was lead rather than zinc, the latter metal being of little use in those days. The separation of the mixture of zinc, galena and pyrite proved too much of a problem for the success of the operations.

The results of the early exploration are to be seen in a shaft which was sunk on the more northerly deposit near the road, which is but a little distance from the Arnold talc mine. The depth of the shaft is uncertain, it being now partly filled with water, but is probably not over 75 feet. On the side hill below the outcrop a tunnel has been driven into the hanging so as to give access to the shaft workings and partly drain them. This may have been excavated at a later date than the exploratory work described by Emmons, but there seems to be no record of the time or of those interested in the renewal of operations. The body that is explored by the shaft outcrops at the surface to the southwest as a rusty

band in the limestones, ranging from a few inches to several feet thick. It can be traced for quite a distance in that direction. Underground it shows the same variation in thickness.

Some of the ore from the early operations was still to be seen recently about the shaft. In its content of galena which is fairly abundant in much of the material, it differs from the rest of the ores in the Edwards district. I am informed by Mr T. M. Williams, who was able to inspect the workings in some detail that the lead-bearing ore occurs only as a local phase, really as a distinct body from the main sphalerite deposit. In this event it may well be a separate ore concentration formed under different conditions and at a different time, possibly analagous to the lead ores to the north of Gouverneur. It was the galena that was sought by the early prospectors.

The zinc ore from this locality is distinguished by a prevailingly fine granular, dark metallic sphalerite which forms a groundmass for numerous larger grains of pyrite. The sphalerite particles are usually measurable by a few hundredths of an inch, while the average diameter of the pyrite is perhaps one-fourth of an inch. The ore from the more or less weathered outcrop has a loose somewhat crumbly texture.

A secondary exploratory shaft has been put down on the Balmat property about 1000 feet to the south and east of the first, on what is apparently a parallel body on the footwall side. Little information about this occurrence could be gained at the time of the writer's visit, the workings having become inaccessible by caving.

Streeter Place

On the trend of the more easterly Balmat deposit and across the Fowler road occurs a well-defined band of ore which can be traced for some distance along its northeasterly course. Its outcrop is on the northerly side of a low ridge of limestone, next to a small swamp under which the ore extends on the dip with a higher bluff of limestone on the opposite side of the swamp. The tract is a part of the Streeter place, according to Mr J. H. McLear of Gouverneur, to whom I am indebted for many facts in regard to the property ownership in this section.

The limestone and the ore outcrop is covered with soil and drift, except here and there, so that the full extent of the deposit and its relation if any to the Balmat leads are not certain, but it appears to be of substantial character. It has been explored in three places by

shallow pits, of which the central one is the largest and deepest. Apparently the exploration was performed many years since, and may be contemporary with the early work on the Balmat, although there is no mention of the Streeter property in the reports of the First Survey which refer to the adjacent deposits.

The ore is 6–8 feet thick in the face exposed in the central pit, while the hanging wall is more or less charged with sulphides for a couple of feet more. The dip seems to be about 30° northwest, but there is some uncertainty in regard to the matter owing to the small extent of the exposure. The limestone in the vicinity shows contortion, so that its attitude is subject to quick changes of dip and strike; the general trend however is nearly northeast and the dip 30–45° northwest. The same admixture of serpentine and talc characterizes the beds as has been noted for many of the other ore-bearing localities. On the hanging side of the ore, less than one-fourth of a mile distant, is a zone of fibrous and foliated talc that has been mined for many years.

The ore has much the same appearance as that on the Balmat place, but there is no galena to be seen from macroscopic examination. The blende is of dark color and metallic lustre. In texture it is finely granular, the particles averaging between one and two-tenths of an inch in diameter. The associated pyrite occurs in two forms, in part as minute particles of generally cubic habit, sometimes showing distinct crystal boundaries, and in part as coarse irregularly bounded masses which may be seen to enclose occasional sphalerite grains. The latter are perhaps secondary growths. All of the ore contains unreplaced carbonates which are usually apparent to the eye.

No prospecting has been done on the deposit in recent years, although it must be considered as one of the more promising occurrences in the district. The lack of attention may be ascribed to the difficulty — not uncommon in St Lawrence county — of securing title to the mineral rights on the property owing to their divided ownership. There is some hope, I understand, that this impediment will soon be overcome.

Dominion Company's Property, Sylvia Lake

On the west side of the Fowler road, within a short distance of Sylvia lake, is a deposit of zinc ore owned by the Dominion Company of Gouverneur. The property lies along the branch road that turns off from the main road to the southwest, as indicated by the

dotted line on the topographic maps. It is a part of the original Balmat estate, as I am informed by Mr J. H. McLear of the Dominion Company, but represents a separate interest as to mineral rights from the Balmat mine already described. The deposit, also, belongs to a distinct ore zone, lying to the northwest of the Balmat-Streeter zone, and farther within the limestone area.

The principal opening on the property consists of a shaft put down on the side of a former pit from which iron ore was mined some 30 years or more ago for the Fullerville furnace now dismantled. The presence of zinc was suspected by reason of the pyrite that appeared in the material from the bottom of the pit at about 25 feet depth. Some samples of this ore were examined by the writer who confirmed the existence of sphalerite in a finely divided condition, along with pyrite, in a mass otherwise composed of iron oxides and vein quartz. The extreme fineness of the grain and the plentiful admixture of vitreous quartz distinguish the ore from this locality from the other occurrences in the district.

The results of exploration which has extended to a depth of 135 feet on an incline of 15–18° indicate that the deposit has the form of a shoot, at least in the upper oxidized portion. Practically all of the ore is comprised within the limits of the shaft workings. In the lowest part, however, the sulphides extend across the shaft on the normal northeast strike and show indications of taking the form of a band or lens in common with the other occurrences. On the surface the continuation of the same lead may be observed by outcroppings of weathered material for a considerable distance northeast of the shaft. At about 1000 feet distant the unaltered sulphides are shown in a shallow working over a width of 12 feet or more.

It would appear that the peculiar conditions encountered in the shaft are the result of purely local influence, and that if the ore continues in depth it will probably change to the ordinary type as exemplified by the other deposits in the vicinity. There has occurred a deep oxidation of the ore, with a secondary migration of some of the zinc from the weathered part of the deposit — a result that can be traced back no doubt to preglacial times. The fact that the iron is in the form of hematite, rather than limonite, indicates a difference of conditions from those obtaining at present where limonite is the single product of weathering. Nowhere else has the process of oxidation continued to such depth and the reconcentration of the zinc been so well defined. In view of all the facts that have been brought to light it seems probable that the deposit originally was of the normal type — a mixture of pyrite

and sphalerite in the form of a lens or band — and that by reason of local fracturing or some other physical feature that favored the process, the ore was subjected to deep oxidation in a circumscribed area. As the result of this oxidation the pyrite was converted into hematite and the sphalerite probably into zinc sulphate which was then partially reprecipitated as sphalerite in contact with the sulphides lower down. The migration of the ores was effected by ground waters working along the dip of the body and their influence is to be seen also in the admixture of vein quartz that accompanies the ore. The weathering and secondary concentration may well have taken place under the cover of the Potsdam sandstone which spread over the area previous to Glacial time.

A little north of the zinc deposit occurs a band of talc which has been explored in recent years. The sulphides occur thus between two parallel talc beds, the main one being to the south on which the Arnold, Wight and Columbia mines are located and which lies on the hanging side of the Balmat-Streeter zinc deposits.

Cemetery Lot

This locality is southwest of Balmat Corners and nearly due south of the Balmat line, close to the border of the limestone belt. The contact of the limestone with the hard formations is quite involved in the section east of Sylvia lake, as shown in the sketch map, but on the south side it sweeps around in a broad curve at a distance of a mile or less from the lake shore. In the stretch southwest of Balmat Corners it lies just south of the Fullerville road. The limestone near the contact is very impure, showing talc and serpentine inclusions and intercalated quartz bands which in many places constitute more than one-half of the mass. Its attitude is difficult to determine, but in general it seems to follow the usual northeasterly course and to dip northwest.

The zinc showing is on the south side of the ridge which crosses the Fullerville road and which is partly occupied by a cemetery. The presence of ore here was discovered by Arthur Scott who performed the little exploration that so far shows a band of rich blende and pyrite near the base of the ridge, with a width of 2 feet or a little more and of undetermined length. The strike is northeast and the dip southwest. On the hanging side a smaller band makes off into the limestone at nearly right angles.

The occurrence has interest, aside from whatever commercial importance may be attached to it, by reason of the evidences of

secondary mineral growth in the ore and wall rocks, rarely to be seen in so clearly marked examples elsewhere in the district. The ore band apparently has been a locus of considerable compression and deformation; it is traversed by many fractures in which secondary carbonates, mainly calcite, have been deposited in rhombohedral aggregates. This later material contains no sulphides. There is a second generation of pyrite which takes the form of large individuals — 2 or 3 inches in diameter — that have one or more crystal boundaries and that are not intergrown with the sphalerite as are the smaller grains of the groundmass. The sphalerite itself has undergone a partial rearrangement, and the stringer of ore in the hanging wall is probably the result of a secondary migration under the same conditions which led to the recrystallization of the ingredients.

The ore is fairly rich and its character is such that it could be easily concentrated.

Rhodes Place

Two or three prospects, in which a good quality of ore is revealed, are to be seen on the Rhodes farm near Talcville, directly opposite the Uniform Fibrous Talc Company's mine and mill, just southwest of that place. The Dominion Company performed the first work which consisted in the sinking of shallow pits on the outcrops. Later (1917) the Grasselli Chemical Company of Cleveland, O., undertook their exploration, making use largely of the diamond drill. The ore occurs in lenses or bands on the north and south slopes of a rather prominent limestone ridge which has been dissected by the Oswegatchie so as to leave a small outlier on the northern bank that is known locally as Wintergreen hill. The Edwards railroad traverses the ridge also in a cut on the north side next to the river.

One of the ore showings lies up the hill, 100 feet or so south of the railroad cut, near an abandoned talc mine. It consists of 2–3 feet of sulphides, of medium texture and averaging well in zinc content. The ore resembles much the product from the Edwards mines. The carbonates have been largely replaced and the main gangue material is serpentine and talc. The lens had been followed to a depth of 25 feet when seen by the writer.

At a distance of 500 feet southwest of this occurrence, across the summit of the ridge, a second showing, with a small but rich lead, has been under prospect. Here the strike is uncertain, but it would appear to be nearly north, so that the two occurrences if on the

same deposit, are connected by a fold which swings around the western shoulder of the hill. There is evidence of considerable deformation in the limestones which show no consistent readings of dip and strike, while the included silicate bands are much contorted.

A feature of the outcropping part of the deposits is the presence in places of a greenish yellow coating on the sulphides. It reacts for cadmium and probably is a more or less impure form of the mineral greenockite. It is of an earthy granular texture, never apparently taking crystal form.

Various Other Occurrences

A little prospecting has been performed by a Gouverneur party on the Davis farm, northwest of the Pleasant Valley school house, in the middle of the limestone belt and nearly south of Talcville. The farm is shown on the contour map at the end of the branch road which connects with the Edwards-Fullerville road just west of the school. The blende occurs as a dissemination within the limestone and so far as explored is of relatively lean character.

On the McGill farm, on the Edwards road from Pleasant Valley school, and just south of the large quartzite ridge, there are scattered bunches and disseminations of sphalerite. Some blasting was done at one locality close by the road about where the latter crosses the 700-foot contour on the map. It failed to show any defined body of ore, although samples were obtainable which carried as much as 10–15% zinc. This work was done by Messrs. Potter and Finch of Gouverneur.

Disseminated blende and pyrite are to be seen in several places on the Austin farm, northeast of Sylvia lake.

A showing of rich blende, practically free of pyrite admixture, is to be seen directly on the shores of Sylvia lake, partly under water. The occurrence is about one-half mile southwest of the one on the Dominion Company's lands and is reported to be held under lease by the Northern Ore Company.

At the Falls on the West Branch, about 3 miles above Fullerville, and just off the Gouverneur sheet an occurrence of sphalerite has been reported by J. C. Finch. There is only a small quantity of the ore in evidence, but it has interest as showing the continuation of the limestone in an offshoot of the main belt much farther south than had been supposed.